Self-reported Anthropometric Tools for Screening Children with Overweight/Obesity Status and A Clustering of Cardiometabolic Risk Factors

CHAN, Po Tai

A Thesis Submitted in Partial Fulfilment
of the Requirements for the Degree of
Doctor of Philosophy
in
Social Medicine

The Chinese University of Hong Kong

September 2011

Thesis/ Assessment Committee

Prof. Xiaorong Wang (Chair)

Prof. Tony Nelson (Thesis Supervisor)

Prof. Kai-chow Choi (Thesis Co-supervisor)

Prof. Jean Kim (Committee Member)

Professor David H. McCarthy (External Examiner)

Academic Honesty Declaration

I declare that the assignment here submitted is original except for source material explicitly acknowledged, the same or closely related material has not been previously submitted for same or different courses, and that the submitted soft copy with details listed in the <Submission Details> is identical to the hard copy(ies), if any, which has(have) been / is(are) going to be submitted. I also acknowledge that I am aware of University policy and regulations on honesty in academic work, and of the disciplinary guidelines and procedures applicable to breaches of such policy and regulations, as contained in the website http://www.cuhk.edu.hk/policy/academichonesty/.

____________________	25th July 2011
Signature	Date
Chan Po Tai	1006357550
Name	Student ID
50069	Doctor of Philosophy in Social Medicine
Course code	Course title

Table of Contents

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of Variance
AUC-ROCs	Area Under Receiver Operator Characteristic Curves
BH	Body Height
BMI	Body Mass Index
BP	Blood Pressure
BT	Breast Tanner
BW	Body Weight
CI	Confidence Interval
CMRF	Cardiometabolic Risk Factors
GT	Male Genitalia Tanner
HDL-C	High-Density Lipoprotein Cholesterol
ICC	Intra-Class Correlation Coefficient
LDL-C	Low-Density Lipoprotein Cholesterol
MBH	Measured Body Height
MBW	Measured Body Weight
MWC	Measured Waist Circumference
NPV	Negative Predictive Value
PDS	Pubertal Developmental Scale
PH	Pubic Hair
PPV	Positive Predictive Value
REF	Reference Group
SD	Standard Deviation
SE	Standard Error
SRBH	Self-Reported Body Height
SRBW	Self-Reported Body Weight
SRDBMI	Self-Reported Derived BMI

SRWC	Self-Reported Waist Circumference
TDCS	Tanner Derived Composite Stage
WC	Waist Circumference
WHtR	Waist To Height Ratio
ZWC	Waist Circumference (Z Score)
α	Risk Score
β	Cardiovascular Risk Score
R^2	Variance
p	P-Value
p ($\triangle$F)	P-Value Testing The Significance Of F Change From The Preceding Model
B	Un-Standardized Regression Coefficient

ABSTRACT

Background

The increasing rate of overweight/obesity in children is a serious public health problem worldwide. Childhood obesity has been shown to be associated with a clustering of cardiometabolic risk factors (CMRFs) leading to cardiovascular diseases and diabetes mellitus in later life and premature mortality. Puberty has a complex, entwined relationship with the various CMRFs particularly high body mass index (BMI) and large waist circumference (WC). Self-report method is commonly used for obtaining anthropometric measures and pubertal assessment data because of its simplicity, low cost and non-invasiveness. Self-reported body weight (SRBW) and self-reported body height (SRBH) derived BMI (SRDBMI) and self-reported WC (SRWC) may be useful assessment tools for screening and monitoring the prevalence of overweight/obesity. We assessed the agreement of self-reported Tanner pubertal questionnaire and self-reported Pubertal Development Scale (PDS), SRBW, SRBH and SRWC with measured values. We also examined the diagnostic ability of SRDBMI and SRWC in classifying children with overweight/obesity status and CMRFs clustering. Furthermore, we explored whether consideration of pubertal staging is needed for identifying children/adolescents with a clustering of CMRFs and its moderating effect on predicting cardiometabolic risk by WC or BMI.

Methods

This thesis is composed of two cross-sectional studies and all children/adolescents were recruited from school settings. The first study recruited children/adolescents from a convenience sample aged between 8 and 18 years. The aim of the first study was to assess the agreement of the Tanner pubertal self-reported questionnaire and the self-reported PDS with raters' assessments. Children/adolescents were given

Chinese versions of the Tanner pubertal questionnaires, followed by a Chinese PDS to fill out, before undergoing visual depiction physical examination by a same gender rater who was experienced in Tanner staging in a private room. The raters were unaware of the results of the two self-reported questionnaires. The second study recruited children/adolescents, aged between 6 and 18 years using cluster random sampling, from February 2007 to April 2008. A self-administered questionnaire which included questions on demographic data, the two validated self-reported pubertal questionnaires and anthropometric measurements was given to children/adolescents to bring home for completion. Anthropometric measurements, blood pressure (BP) and fasting blood samples for measurements of fasting plasma glucose and lipid profile were taken by trained research staff after the children/adolescents returned the questionnaire on the day of the survey.

Results

Analyses demonstrated good consistency between Tanner self-reported pubertal questionnaire, self-reported PDS, SRBW, SRBH, SRWC and measured values. The SRDBMI and SRWC showed similar diagnostic ability to their measured counterparts to identify children/adolescents with overweight, obesity status and CMRFs clustering. Although no significant association was found between pubertal stages and CMRFs clustering, which may be due to the small numbers of children/adolescents having CMRFs clustering, pubertal stage was found to be significantly associated with individual CMRFs namely large WC, increased triglycerides, and elevated BP in boys and large WC and elevated BP in girls. Pubertal stage has a significant moderator effect on the prediction of CMRFs by WC or BMI.

Conclusion

SRDBMI and SRWC are valuable screening anthropometric tools to identify children/adolescents with overweight/obesity in community settings and public health/epidemiological research in Hong Kong when cost, privacy and other concerns preclude the use of physical assessment. Furthermore, the effect of puberty on the prediction of CMRFs warrants further research into the relationship between puberty, obesity and CMRFs.

摘要

背景

日益增加的兒童超重/肥胖比率已成為一嚴重的全球公共衛生問題。兒童肥胖已被證明與一集群的心臟代謝危險因素（CMRFs）有關，並會導致心血管疾病、糖尿病及過早死亡。青春期與心臟代謝危險因素之間則存在一個複雜及緊扣的關係，尤以在擁有過高身體質量指數（BMI）和腰圍(WC）比較一般的標準過大(≥90 percentile)的人為甚。自我評量方法不但簡單，而且成本甚低，並為非侵入性，所以經常被用於人體測量和青春期評估的數據收集。自我評量的體重（SRBW）及自我評量的身高（SRBH）所計算出的身體質量指數（SRDBMI）和自我評量的腰圍（SRWC）可能是甄別和監測超重/肥胖的盛行率之有效工具。我們評估了 Tanner 青春期自我評量問卷、自我評量的青春期發育程度（PDS）、SRBW、SRBH 和 SRWC 之可靠性。我們亦研究了 SRDBMI 和 SRWC 在兒童超重/肥胖的甄別和 CMRFs 集群的診斷能力。此外，我們探討了青春期狀態於甄別具有心臟代謝危險因素集群的兒童的作用及其對預測CMRFs 的調節作用。

方法

此論文由兩個橫斷面研究所組成，而研究中所有兒童均是從學校招募的。第一項研究採用方便抽樣的方式招募兒童，年齡介乎 8 至 18 歲。第一項研究的目的為評估 Tanner 青春期自我評量問卷及自我評量的青春期發育程度之可靠性。研究人員向兒童派發了中文版本的 Tanner 青春期自我評量問卷及青春期發育程度問卷，填寫後，兒童再被安排到一私人房間進行視察身體評估，評估人員與兒童性別相同，並擁有 Tanner staging 的經驗。評估人員對先前兩個問卷所填寫的答案並不知情。第二項研究在二零零七年二月至二零零八年四月期

間進行，採用了集群隨機抽樣的方式招募兒童，年齡介乎 6 至 18 歲。兒童獲派一份須自行填寫的問卷，在家完成。問卷內容包括年齡及性別等基本資料及人體測量的數值。兒童在提交問卷後，會在同一天被安排由經過訓練的研究人員進行人體測量，血壓量度（BP）及空腹血液樣本的抽取（作測量空腹血糖及血脂之用）。

結果

可靠性分析展示了 Tanner 自我評量青春期問卷、自我評量的青春期發育程度、SRBW、SRBH、SRWC 和實際測量值之間有良好的一致性。SRDBMI 及 SRWC 能準確地甄別超重/肥胖的兒童及其 CMRFs 集群。雖然由於樣本數目少，研究並無發現青春期階段與 CMRFs 集群之間的關係，但研究顯示青春期階段與個別的CMRFs，存在明顯的關係。以男童而言，該等 CMRFs 包括腰圍過大、血液含過高的三酸甘油脂及高血壓；以女童而言，該等 CMRFs 則包括腰圍過大及高血壓。青春期對於以 WC 和 BMI 預測 CMRFs 有重大的調節作用。

結論

在社區、臨床治療和公共衛生研究的範疇上，SRDBMI 及 SRWC 能作為有效的人體測量工具，用以甄別超重/肥胖的兒童。身體評估需要較高的成本，亦有私隱的問題及其他關注，但 SRDBMI 及 SRWC 則不存在此問題。此外，青春期對預測CMRFs 的影響闡明了青春期、肥胖及 CMRFs 之間的關係仍須作進一步研究。

ACKNOWLEDGEMENTS

The research presented in this thesis is a part of a large scale sleep study. It was supported by funding from the Research Grants Council (CUHK4465/06M), and Shaw College of the Chinese University of Hong Kong.

I would like to express my gratitude to the following experts and people who have made the completion of my research and thesis possible:

To Prof. Tony Nelson, my principal supervisor, for his expert advice, constructive comment, enthusiasm, unremitting support and constant inspiration during my study and in completion of my thesis;

To Dr. Kai Choi, my co-supervisor, for his expert guidance, coaching and unremitting support and supervision in statistical data analyses and constructive comment in completion of my thesis;

To Prof. Rita Sung for her expert advice in childhood obesity;

To Prof. Alice Kong and Prof. Juliana Chan for providing me an opportunity to take part in data collection, data entry and access to the database of the sleep study for my thesis data analyses;

To Prof. Gary Wong for providing pubertal assessment training to me;

To Prof. Otto Wong for his expert advice on the development of my PhD study proposal;

To Prof William Goggin for his expert statistical advice on the report entitled "Reliability of pubertal self-assessment in Hong Kong Chinese children".

To Mr Yee Kit Tse for his expert statistical advice on the report entitled "Measurement of pubertal status with a Chinese self-reported Pubertal Development Scale".

To Dr H.K. So for his assistance in assessing pubertal stage of male students;

To Dr. K. Tang Mr. G. Tang and Ms L.K. Yu for their ongoing support and valuable advice;

To Prof. Naomi M. Morris and J. Richard Udry for their kind permission to use the line drawings pubertal assessment questionnaire;

To Prof A.C. Petersen and Prof L. Crockett for their kind permission to use the pubertal development scale;

To Ms Joyce Leung, the Project Co-ordinator (RPg) of the PhD programme in Social Medicine for her enthusiasm and ongoing support;

To the research staff of the sleep study for their support and valuable contributions;

To Dr C.W. Yu and Mr F.B. Tsang for their support in the pubertal assessment study.

Finally, special thanks are given to the student helpers from the Shaw College of the Chinese University, all children/adolescents who participated in the pubertal assessment study and the sleep study, the Pentecostal Lam Hon Kwong School, Lam Tai Fai College, FDBWA Mrs Fung Ping Shan Primary School for their assistance, diligence, and staunch support in the pubertal assessment study.

PEER-REVIEWED PUBLICATIONS

Listed below are the peer-reviewed publications and conference presentations that have resulted from this thesis.

Chan, N.P.T., Choi, K.C., Nelson, E.A.S., Sung, R.Y.T., & Kong, A.P.S. (2011). Can self-reported waist circumference be used as a screening tool for identifying children with cardiovascular risk and overweight/obese status? *International Journal of Cardiology,* Supplement 1, volume 147, p.S30-S31, (P075).

Chan, N.P.T., Sung, R.Y.T., Nelson, E.A.S., So, H.K., Tse,Y.K., & Kong, A.P.S. (2010). Measurement of pubertal status with a Chinese self-report Pubertal Development Scale. *Matern Child Health J. 14*:466–473.

Chan N.P., Sung, R.Y.T., Kong, A.P.S., Goggins, W.B., So, H.K., Tse. Y.K., & Nelson, E.A.S. (2010).Measurement of Pubertal Status with a Chinese Self-Assessment Tanner Pubertal Questionnaire and a Self-Report Pubertal Development Scale. *European Heart Journal Supplements: Journal of the European Society of cardiology. 12:* Supplement A (P039).

Chan N.P., Choi, K.C., Kong A.P.S., Sung, R.Y.T., & Nelson, E.A.S. (2010). Accuracy of Self-reported Body Weight and Height for Screening Overweight/Obesity in Hong Kong Chinese children? *European Heart Journal Supplements: Journal of the European Society of cardiology. 12:* Supplement A (P040).

Chan, N.P., Sung, R.Y., Kong, A.P., Goggins, W.B., So, H.K., & Nelson, E.A.S. (2008). Reliability of pubertal self-assessment in Hong Kong Chinese children. *Journal of Paediatrics and Child Health, 44*, 353–358.

CONFERENCE PRESENTATIONS

Chan N.P., Choi, K.C., Kong, A.P.S., Sung, R.Y.T., & Nelson, E.A.S. (2010). Self reported waist circumference: A screening tool for identifying children with cardiovascular risk factor and overweight /obesity. Oral presentation in the 5th Hong Kong International Nursing Forum,3-4 June 2011.

Chan N.P., Choi, K.C., Kong, A.P.S., Sung, R.Y.T., & Nelson, E.A.S. (2010). Can self-reported body weight and height be used to screen for overweight/obesity in Hong Kong Chinese children? Poster presentation in the 4th Hong Kong International Nursing Forum, 4-5 June 2010.

Chan N.P., Sung, R.Y.T., Kong, A.P.S., Goggins, W.B., So, H.K., Tse. Y.K., & Nelson, E.A.S. (2010). Measurement of Pubertal Status with a Chinese Self-Assessment Tanner Pubertal Questionnaire and a Self-Report Pubertal Development Scale. *Poster presentation in the International Congress on Cardiology (ICC) Hong Kong 26-28 February 2010.*

Chan N.P., Choi, K.C., Kong A.P.S., Sung, R.Y.T., & Nelson, E.A.S. (2010). Accuracy of Self-reported Body Weight and Height for Screening Overweight/Obesity in Hong Kong Chinese children? *Poster presentation in the International Congress on Cardiology (ICC) Hong Kong 26-28 February 2010.*

Chan N.P., Choi, K.C., Kong, A.P.S., Sung, R.Y.T., & Nelson, E.A.S. (2010). Can self-reported body weight and height be used for overweight/obesity screening in Hong Kong Chinese children? *Proceeding of the 1st International Congress on Abdominal Obesity*, 28-30 Jan 2010.

Chan N.P., Sung, R.Y., Kong, A .P., Goggins, W.B., So, H.K., & Nelson, E.A.S. (2009). Reliability of pubertal self-assessment in Hong Kong Chinese children. *Proceedings of the First Asia-Pacific Conference on Health Promotion and Education (APHPE)*. Makuhari Messe, Japan. 18-20 July, 2009.

RESEARCH FUND

2007-2008 Student Campus Work Scheme 2007-08 of the Shaw College of the Chinese University of Hong Kong HK$7,500

2008-2009 Student Campus Work Scheme 2008-09 of the Shaw College of the Chinese University of Hong Kong HK$7,500

2009-2010 Student Campus Work Scheme 2009-10 of the Shaw College of the Chinese University of Hong Kong HK$5,300

CHAPTER 1

INTRODUCTION AND LITERTURE REVIEW

Preface

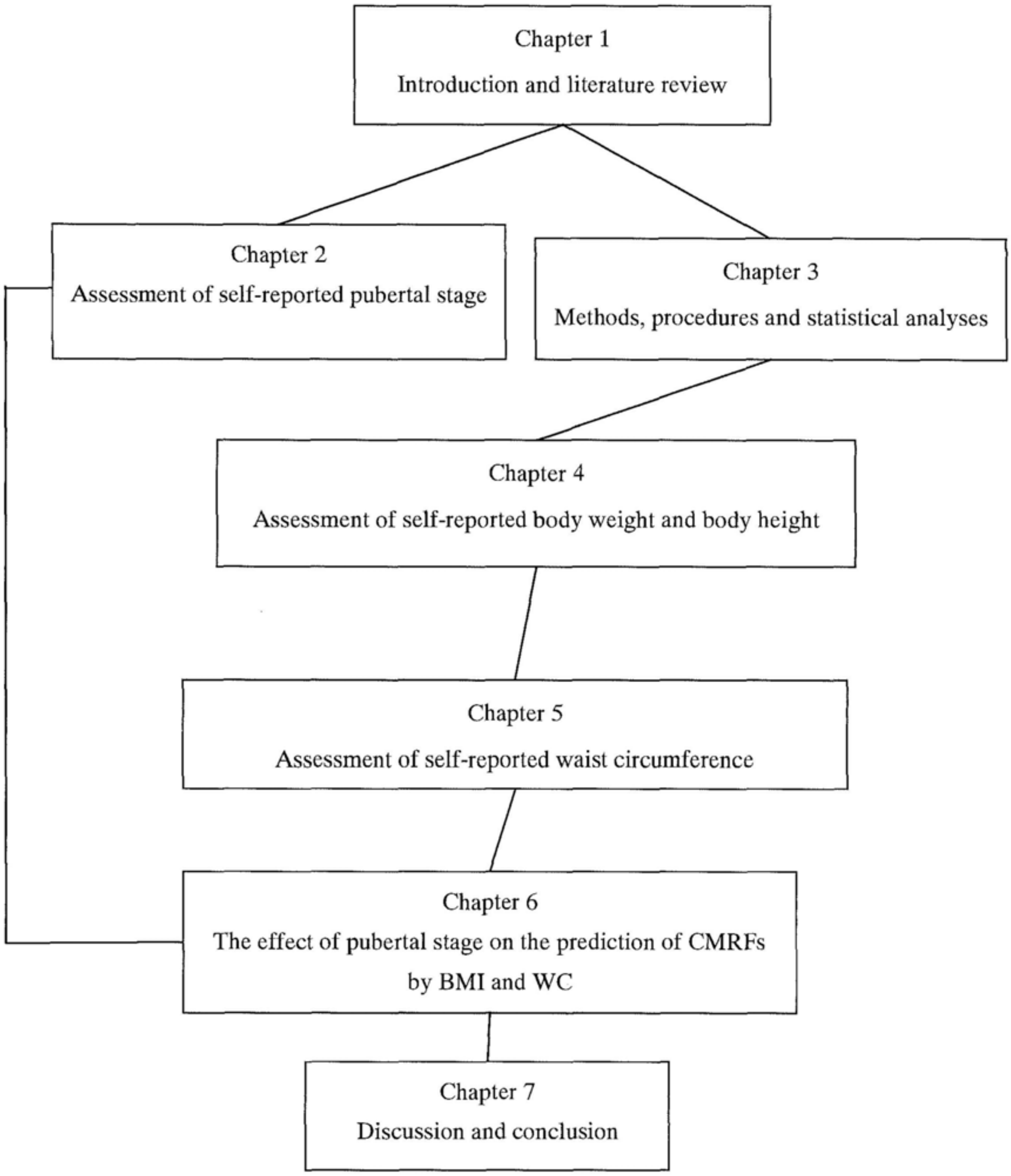
Today, childhood obesity is one of the serious public health problems worldwide and is increasing at an alarming rate in many countries, including Hong Kong. Overweight/obesity in childhood is associated with a clustering of cardiovascular risk factors leading to cardiovascular diseases and diabetes mellitus in later life and premature mortality. Assessing overweight/obesity is an important step in monitoring and preventing the rapid increase of overweight/obesity. There are variety methods for measuring overweight/obesity of children/adolescents. Body mass index (BMI) and waist circumference (WC) are the most common and widely used assessment tools for identifying overweight/obese children/adolescents. Self-reported method has been used to obtain anthropometric measures and pubertal assessment data. However there has been few previously reported study assessing the diagnostic ability of self-reported anthropometric measures such as BMI and WC to classify children/adolescents with overweight/obesity and with a clustering of cardiometabolic risk factors (CMRFs). It is also unclear whether pubertal assessment needs to be taken into consideration when identifying children/adolescents with a clustering of CMRFs. This thesis developed research questions, aims and objectives to further clarify these issues.

Structure of the Thesis:

Figure 1-1 provides an overview of the thesis, which is divided into 7 chapters. Chapter 1 is the introduction and background to the study. The health impacts of childhood obesity are discussed, including hormonal and metabolic consequences. The literature review describes different assessment methods to determine body fatness and discusses the strength and weakness of the measurement tools. The issues related to puberty, obesity and cardiometabolic risk factors are also discussed. The research questions, aims and objectives of the thesis are stated. Chapter 2 assesses the agreement of Tanner pubertal self-reported questionnaire and Chinese self-report Pubertal Development Scale with measured evaluations. The study population of this study was a convenience sample which was recruited from school settings. Chapter 3 describes the methods and procedures of a large scale sleep study entitled "sleep duration, neurohormonal dysregulation and obesity in Hong Kong children and adolescents," which was conducted during the period February 2007 to April 2008. The author of this thesis was able to access the database of the sleep study and use this database to explore new knowledge related to childhood obesity. The overall details of the statistical analyses undertaken for this thesis are described. Chapter 4 assesses the agreement of SRBW and SRBH with measured values and examines the diagnostic ability of SRDBMI to classify children/adolescents with overweight, obesity and CMRFs clustering. Chapter 5 assesses the agreement of SRWC with the measured values and examines the diagnostic ability of SRWC to classify children/adolescents with overweight, obesity and CMRFs clustering. Chapter 6 investigates the association between pubertal stage and CMRFs clustering and the effect of pubertal stage on the prediction of CMRFs by BMI and WC. Chapter 7 summarizes the findings and discusses the results of the studies, considering whether the aims and objectives have been met. It concludes with a discussion of the strength and weakness of the studies in this thesis. Finally, suggestions are made for the possibilities for knowledge transfer of these results and possible directions for future work.

As chapters 2, 4, 5 and 6 were based on five scientific papers that have been published or submitted for publication to peer-reviewed scientific research journals, there may be some duplication in the introduction and discussion sections of these chapters.

Fig 1-1 Overview of the thesis structure



INTRODUCTION

Background to the study

General definitions

Overweight and obesity are defined as a state of pathologically excessive adipose tissue mass, conferring a higher risk of cardiovascular and metabolic disorders (Gil-Campos et al., 2004, World Health Organization, 2011). Alternatively overweight/obesity have been defined as having abnormal or excessive fat accumulation that may impair health (World Health Organisation, 2011).

Prevalence of overweight and obesity

The prevalence of childhood obesity is increasing rapidly worldwide and reaching epidemic proportions (Ebbeling, Pawlak, & Ludwig, 2002; World Health Organization, 2010). Between the 1970s and 1990s, the prevalence of obesity in children doubled or trebled in Australia, Brazil, Canada, Chile, Finland, France, Germany, Greece, Japan, the United Kingdom, and the United States (Han, Lawlor, & Kimm, 2010; Wang & Lobstein, 2006). Experts estimated that childhood overweight/obesity would increase to more than 40% of children in the North American and Eastern Mediterranean WHO regions, 38% in Europe, 27% in the Western Pacific, and 22% in Southeast Asia by 2010 (Kipping, Jago, & Lawlor, 2008; Ogden, Carroll, & Flegal, 2008; Sundblom, Petzold, Rasmussen, Callmer, & Lissner, 2008). In 2010, WHO estimated that nearly 43 million children under the age of 5 years were overweight globally. WHO considers the rapid increase in the rate of overweight/obesity in children as one of the greatest threats and challenges to public health of the 21st century (World Health Organization, 2010).

During the past two decades, the rates of overweight/obesity in Hong Kong children/adolescents have also dramatically increased. The prevalence of overweight/obesity in children/adolescents aged 6-18 years increased by about 9% (from 16.7% to 25.5%) for boys and by about 4% (from 16.7% to 20.6%) for girls from 1993 to 2005/06 respectively, using the ≥85 percentile as the cutoff to define both overweight and obesity and the ≥95 percentile to define obesity (So et al., 2008). If the International Obesity Task Force definitions (Cole, Bellizzi, Flegal, & Dietz, 2000) are used to define overweight and obesity cut-offs in Hong Kong Chinese children/adolescents, then 20.9% boys and 13.5% girls, aged 6-18 years, were overweight/ obese in 2005/06 (So, et al., 2008). The annual increase in the prevalence of childhood obesity in Hong Kong is approximately 0.5 percent over the past decade, and is similar to that of other countries such as the United States (So, et al., 2008).

Health consequences of childhood obesity

Increasing obesity prevalence among children and adolescents is one of the leading public health problems globally (Ebbeling, et al., 2002). There is a wealth of evidence that overweight/obesity is related to adverse health risks (Bray, 2004). Overweight/obesity is associated with a clustering of cardiometabolic risk factors (CMRFs) including elevated serum levels of triglycerides, elevated low-density lipoprotein cholesterol (LDL-C), low serum levels of high-density lipoprotein cholesterol (HDL-C), elevated blood pressure and impaired blood glucose tolerance (Burke et al., 2004; Katzmarzyk et al., 2001; Freedman, Khan, Dietz, Srinivasan, & Berenson, 2001). Even children at younger ages (9-12 years) with mild-to-moderate degrees of overweight have been found to have impaired arterial endothelial function and increased intima-medial thickness of their carotid arteries (Fang, Zhang, Luo, Yu, & Lv, 2010; Woo et al., 2004a &2004b). The Bogalusa Heart Study found that 77% obese children remained obese in adulthood (Freedman, et al., 2001; Vanhala, Vanhala, Kumpusalo, Halonen, & Takala, 1998). Obese children are associated with an elevation of cardiovascular risk and ischemic heart disease in later life (Despres, 2007) and would likely retain their obesity-related risks for the rest of their lives with resultant premature morbidity and mortality (Karnehed, Rasmussen, & Kark, 2007).

LITERATURE REVIEW

Measurement of body fatness

Assessment of body fat can be done using a variety of methods ranging from simple to complex with all methods having limitations and some degree of measurement error. Methods used to measure body composition include computed tomography, magnetic resonance imaging, dual energy X-ray absorptiometry and underwater weighing and bioelectrical impedance analysis. Dual energy x-ray absorptiometry provides overall and regional measurement of body compositions including body fat, lean mass and bone mass. Computed tomography and magnetic resonance imaging are precise and accurate, give information on total and regional percentage of fat and are considered as the reference method for measuring the quantity of intra-abdominal adipose tissue in children/adolescents (Benfield et al., 2008; Brambilla et al., 2006; Hoffer, 2005; Shen et al., 2003). However, computed tomography, dual energy x-ray absorptiometry and magnetic resonance imaging are expensive, require technical and radiological expertise to perform the procedure and interpret the results. In addition, computed tomography and dual energy x-ray absorptiometry require that participants be exposed to radioactivity. All these limitations would preclude their use in clinical practice, epidemiological or field studies. Underwater weighing is used to assess the level of body fatness by weighing a person in air and under water and comparing the difference in weight (Pietrobelli & Tato, 2005). Although underwater weighing is relatively accurate, good for measuring changes in percentage of body fat, it overestimates percentage of fat in athletes, e.g. bodybuilders, with high fat-free mass. Furthermore, underwater weighing is time consuming and requires a bulky apparatus filled with water for the participant to submerse into water which would cause discomfort. Computed tomography, magnetic resonance imaging, dual energy x-ray absorptiometry and underwater weighing measurements are impractical in the community or epidemiological research settings as these diagnostic tests are costly, limited to small-scale studies, and lack portability.

Bioelectrical impedance analysis is used for predicting total body water and assumes 73.2% of fat-free mass is water. Hence body fat can be derived from fat-free mass. . Bioelectrical impedance analysis can be measured using a portable scale for assessing the percentage of body fat. It has been used in several large scale studies (Chumlea et al., 2002; Kubo et al., 2010; Loftin et al., 2007; Lohman et al., 2000) for estimating body composition, e.g. the 3rd National Health and Nutrition Survey (Chumlea, et al., 2002), the Project Heartbeat (Mueller, Harris, & Labather, 2004) and the Family Lifestyle, Activity, Movement and Eating (FLAME) study (Carter, Taylor, Williams, & Taylor, 2011). Bioelectrical impedance analysis passes a small and safe electrical current through the body fluids contained in muscle tissue. When Bioelectrical impedance analysis electrical current passes through fat mass, it encounters resistance. The measured resistance is called 'bioelectrical impedance'. When computing %BF, other information including age, gender, BW and BH of the participant are required because the resistance of fat mass and fat-free mass are affected by body sizes and body frame. Although bioelectrical impedance analysis is less accurate than the sophisticated measurements such as computed tomography and magnetic resonance imaging, bioelectrical impedance analysis measurement scales are relatively inexpensive, portable, simple and quick, and do not require extensive training. However, bioelectrical impedance analysis has been criticized for its inaccuracy because other variables such as BH, age and gender, are needed for %BF calculation. Possible sources of errors including hydration levels, bladder status, food intake, and skin temperature would affect the accuracy of the measurement results. Bioelectrical impedance analysis also underestimates the %BF when both thighs are in contact with each other (Kyle, Bosaeus, De Lorenzo, Deurenberg, Elia, Gómez, et al., 2004a & 2004b; Lee & Gallagher, 2008). Studies have found that foot-to-foot bioelectrical impedance analysis does not provide accurate measurements of body composition for a considerable proportion of overweight or obese children/adolescents (Lazzer, Boirie, Meyer, & Vermorel, 2003; Radley et al., 2009). Anthropometric indices such as body mass index (BMI) and waist circumference (WC) are simple and may provide more accurate estimates of relative changes in total and truncal fat than bioelectrical impedance analysis is able to do (Aslam et al., 2009).

Table 1.1 Common methods used to measure body fat

Method	Methodology	Strength	Weaknesses
Computerised Tomography	Uses x-rays that pass through the body at different angles to create cross-sectional pictures of the body	Produces high-resolution cross-sectional internal images (Pietrobelli, Peroni, & Faith, 2003)	Exposure to radiation, expensive, limited to research setting (Pietrobelli, et al., 2003)
Dual-Energy X-ray Absorptiometry	Two X-ray beams of different energy levels are passed through the subject with the differential attenuation measured	Ability to measure both regional and total body composition with low radiation dose (Pietrobelli, et al., 2003)	Exposure to radiation, expensive, limited to research settings.
Magnetic Resonance Imaging (MRI)	Uses strong magnetic fields and radio waves to produce cross-sectional internal images	Produces high-resolution cross-sectional internal images, no ionizing radiation as compared to CT (Pietrobelli, et al., 2003)	Expensive, limited to research setting, may cause claustrophobia (Pietrobelli, et al., 2003)
Underwater weighing	The subject is weighed outside the tank first and then weighed again while being submerged in a large tank of water with maximal expiration (Pietrobelli & Tato, 2005)	Relatively accurate Good for measuring change in body fat	Time-consuming, expensive and uncomfortable (Brodie, Moscrip, & Hutcheson, 1998)
Bioelectrical Impedance Analysis	Measurement %BF Attach electrodes to the subject and passing a small; undetectable by subject current for measurement	Quick, easy to perform, portable and inexpensive (Tyrrell et al., 2001)	Less accurate (McCarthy, Cole, Fry, Jebb, & Prentice, 2006), may cause error if BW and BH are entered inaccurately
Skin-fold thickness measurements	The subcutaneous fat is measured by pinching the skin holding only the skin and the adipose tissue, then applying the calipers; Common sites of measurement include triceps and subscapula, above the iliac crest, below scapula, & etc.	Simple and inexpensive (Power, Lake, & Cole, 1997).	Subject to inter and intra-observer variations; Difficult to measure reproducibly (Power, et al., 1997). Training for the measurement is required.
Waist to height ratio (WHtR)	WHtR is the ratio of WC divided by BH, WC and BH are measured for calculating waist/height ratio.	Reports have suggested that the cutoff value at 0.5 is simple and effective for identifying overweight individuals and those of normal weight who face higher metabolic risks (Fang et al., 2010).	Involves two measurements which are subjected to inter-observer error, involves calculation and may be subject to calculation error.
Body mass index (BMI)	Require a weight scale and stadiometer for BW and BH measurement respectively, BMI is the ratio of BW in kilograms (kg) divided by BH in meter squared (m^2).	Is commonly used to measure fat mass and fat-free mass Highly reproducible, offers significant correlation with central body fat (Wang et al., 2003).	BMI gives no indication of body fatness distribution; Involves calculation and may subject to calculation error.
Waist circumference (WC)	Using a constant tension tape to wrap around the subject's waist at specific anatomical landmarks.	Highly reproducible, offers significant correlation with total and central body fat (Wang, et al., 2003)	No universally agreed measurement site.

Anthropometric indices for measurement of body fat

Anthropometric indices including skin-fold thickness, body mass index, waist-to-height ratio and waist circumference are commonly used to assess body fatness in children/adolescents.

Skin-fold thickness

Skin-fold thickness measurement can provide an indirect estimate of total body fat especially in an individual with high weight-for-height because of excessive muscularity, e.g. athletes. Skin-fold thickness can be measured at 3 to 9 different standard anatomical sites around the body (The International Society for the Advancement of Kinanthropometry, 2001). These are the triceps and biceps of the upper arms, chest, below the scapula, above the iliac crest, the abdomen, suprascapular, calf and thigh. The measurements are usually taken at the right side for measurements consistency. The assessor grasps and pulls a fold of skin and subcutaneous tissue, but not the muscle, between thumb and forefinger away from the underlying tissue. The calipers are then applied 1 cm below and at right angles to the pull-up fold of skin. The reading in millimeters (mm) should be taken two seconds later. The same site should be measured twice and the mean measurement should be calculated. However, today, no universal agreement is available on skin-fold thickness reference cutoff values for children/adolescents.

Several factors will influence the accuracy of skin-fold thickness measurement results, for example pressure of the caliper head, correct skin fold pinching technique and duplicating the exact measurement locations. The amount of fat mass being pulled out is somewhat subjective because it depends on the skills of the assessor. Skin-fold thickness measurement results may be different when using different types of skin-fold measuring calipers (Gharib & Rasheed, 2009). In addition, skin-fold thickness requires a caliper, standardized training and considerable experience and skill to obtain an accurate skin-fold thickness values (Addo & Himes, 2010). Due to the possible measurement errors involved, it is usually not appropriate to convert skin-fold thickness measures to %BF. The number of sites that can be measured are restricted because the participants need to exposure themselves for most skin-fold thickness measurement except for the triceps and biceps measurement sites. This may induce embarrassment or anxiety to the participants.

Waist-to-height ratio (WHtR)

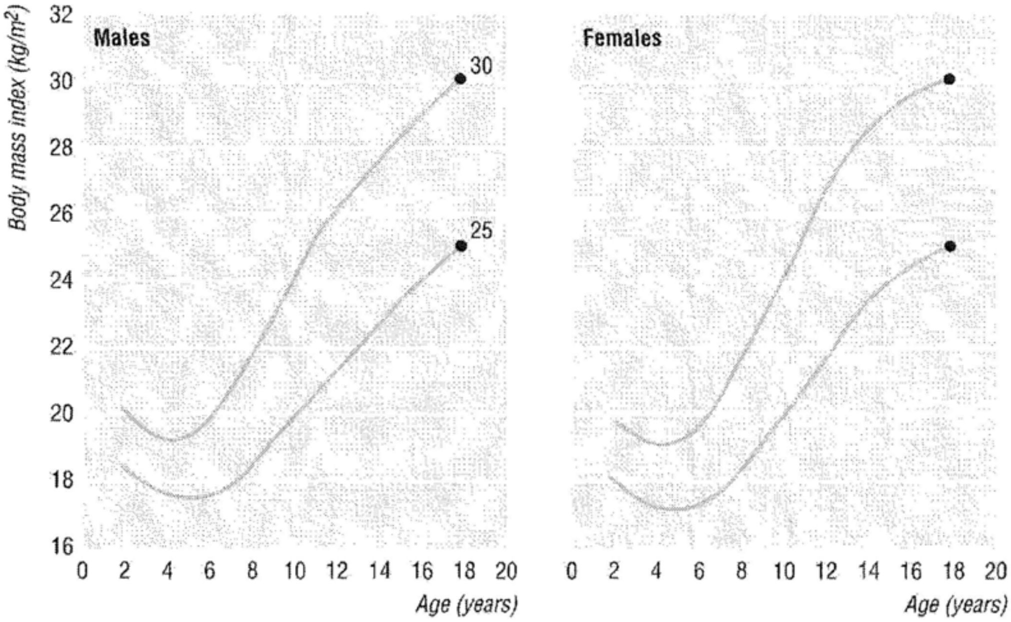
Waist-to-height ratio has been proposed as a convenient alternative measure for assessing central fatness in children/adolescents (Ashwell & Hsieh, 2005). WHtR is defined as WC divided by BH. The WHtR, which reflect central obesity, have been suggested to be a good indicator of predicting CMRFs in children/adolescents (Ashwell & Hsieh, 2005; Campagnolo, Hoffman, & Vitolo, 2010; Ho, Lam, & Janus, 2003; Sung et al., 2008; Yan et al., 2007). Ashwell proposed that a WHtR of 0.5 could be used across all age groups including children/adolescents (Ashwell & Hsieh, 2005). WHtR is a relatively convenient measure, age-independent and does not need age related reference charts (Ashwell, Lejeune, & McPherson, 1996; Hara, Iwata, Okada, & Harada, 2002; Kahn, 2006). However BH and WC of children/adolescents continue to increase during growth and development in children/adolescents. Sung et al. (Sung, et al., 2008) challenged that WHtR is an age-independent measure because fewer of their older children/adolescents participants were categorized as having CMRFs clustering when using 0.5 WHtR cut-off. Currently, there is no universally agreed WHtR reference value available for children/adolescents. Studies showed that WC is an adequate indicator of central adiposity alone and correlates more strongly than WHtR with CMRFs in children/adolescents (Esmaillzadeh, Mirmiran, & Azizi, 2006; Lee, Bacha, Gungor, & Arslanian, 2006; Hirschler et al., 2005; Maffeis et al., 2003; Sung, et al., 2008). Furthermore, Sung et al. (Sung, et al., 2008) suggested that WC with standard measurement site is the simplest clinical measure of central obesity for the prediction of CMRFs in children/adolescents.

Body mass index (BMI)

Of all anthropometric indices, BMI is the most widely used anthropometric measurement tool to quantify and monitor overweight/obesity and to identify an individual who is at increased risk for adiposity-related adverse health outcomes (Bell et al., 2007; Kelishadi et al., 2007). BMI is the measurement of a person's BW in relation to his or her BH. The definition of BMI is the ratio of BW in kilograms (kg) divided by BH in meter squared (m^2). BMI has been found to be highly correlated with body fat and has been used to assess and predict CMRFs clustering in children/adolescents (Cole, et al., 2000; Janssen et al., 2005).

Several leading national and international institutions, including the World Health Organization (WHO), the National Institutes of Health (NIH) and National Heart Lung and Blood Institution have provided guidelines for classifying overweight/obesity based on BMI (National Heart Lung and Blood Institute, 1998; National Institutes of Health, 2011; World Health Organization, 2011). Overweight and obesity have been defined as BMI ≥ 25 kg/m^2 and ≥ 30 kg/m^2 respectively in adults. These overweight and obesity cut-off points provide a benchmark for individual assessment. Data from epidemiological studies demonstrate a direct correlation between BMI and the risk of medical complications and mortality rate (Bell, et al., 2007; Calle, Thun, Petrelli, Rodriguez, & Heath, 1999; Katzmarzyk, Tremblay, Pérusse, Després, & Bouchard, 2003; Zhang, Tse, Deng, & Jiang, 2008). The International Obesity Task Force (IOTF) (Cole, et al., 2000) combined data from 6 national studies, including the United States, Brazil, Great Britain, Hong Kong, the Netherlands, and Singapore, to construct an international BMI-for-age and gender specific reference curve for defining overweight and obesity from toddlers to adolescents between age 2 and 18 years. These reference centile curves passed through the adult BMI overweight and obesity cutoff points 25 kg/m^2 and 30 kg/m^2 respectively so as to makeup the definitions of overweight and obesity in children/adolescents to BMI-for-age ≥ 25 and ≥ 30 kg/m^2 respectively. These cutoff points are less arbitrary than weight-for-height percentile and are based on adult overweight and obesity reference values. The purpose of constructing these centile curves is for international comparisons of prevalence of overweight and obesity in children/adolescents. However, the International Obesity Task Force child overweight and obesity classification has high specificity and low sensitivity. Reilly et al. (Reilly, Dorosty, Emmett, & Avon Longitudinal Study of Pregnancy and Childhood Study Team, 2000) compared the accuracy of the Cole–International Obesity Task Force approach for the diagnosis of children/adolescents overweight/obesity with the standard United Kingdom definition based on United Kingdom BMI for age percentiles to diagnose overweight/obesity in 7-year-old English children. They found that the Cole-International Obesity Task Force BMI definition for children/adolescents underestimated overweight/obesity rate in children/adolescents. This finding is also noted in the Hong Kong Growth Study (So, et al., 2008).

Figure 1.2 International age- and sex-specific BMI cut-off points for classifying overweight and obesity in children/adolescents



Extract from Figure 1-2. International age- and sex-specific BMI cut-off points for classifying overweight and obesity in children/adolescents [Cole TJ, Bellizzi MC, Flegal KM, et al. Establishing a standard definition for child overweight and obesity worldwide: international survey. British Medical Journal 2000; 320(7244):1240-3.].

Currently, there is lack of international consensus on the definition of BMI to define overweight/obesity in children/adolescents. This is due to the effects of age, sex, puberty and ethnicity on growth making the agreement of overweight/obesity on BMI definition difficult. Age, gender and ethnic specific BMI percentile charts are commonly used to define weight status in children/adolescents (Ogden, Carroll, Curtin, Lamb, & Flegal, 2010; World Health Organization, 2006). Overweight and obesity in children are often defined as BMI between ≥85 and <95 percentiles for overweight and ≥ 95 percentiles for obesity (Ogden et al., 2002). In 1993, the Hong Kong Growth Survey defined obesity as weight > [median weight for height × 120%], sex-specific, from birth to 18 years of age (Leung et al., 1996). However, the authors did not define overweight in children/adolescents in their study. A recent Hong Kong Growth Study (2005/06) (So, et al., 2008) using these 3 definitions to compare the prevalence rate of overweight and obesity in Hong Kong Chinese children/adolescents. These 3 definitions were [median weight for height × 120%] (Leung, et al., 1996), BMI-for-age ≥ 25 and ≥ 30 kg/m² (Cole, et al., 2000) and ≥85 and ≥ 95 percentiles (Ogden, et al., 2002) to define overweight and obesity respectively (Table 1.2). They found that the prevalence rates using the Cole - International Obesity Task Force BMI definition to define overweight and obesity were the lowest among the 3 definitions.

Table 1.2 Extract from So et al. Table 5 Overweight and obesity prevalence by gender in Hong Kong children and adolescents using different cut-offs, for data from 1993 and 2006 [p.7 (So, et al., 2008)].

	Boys		Girls		Total	
	1993	2005/6	1993	2005/6	1993	2005/6
International Obesity Task Force cut-offs[9]						
Overweight only (equivalent to adult BMI 25–30)	10.4%	15.8%	7.7%	10.1%	9.0%	13.0%
Obese only (equivalent to adult BMI >= 30)	3.4%	5.1%	1.8%	2.4%	2.6%	3.7%
Overweight and obesity (equivalent to adult BMI >= 25)	13.8%	20.9%	9.5%	13.5%	11.6%	16.7%
Overweight and obese defined as >= 120% median weight-for-height						
Total sample	12.0%	17.4%	9.4%	11.0%	10.7%	14.2%
Sub-sample of students reporting attendance to Student Health Service during previous year (n = 8199) (see text)	-	18.1%	-	10.7%	-	14.4%
Student Health Service estimate *	-	-	-	-	-	18.4%
Percentiles based on 1993 data						
>= 85th percentile	16.7%	25.2%	16.7%	20.6%	16.7%	22.9%
>= 95th percentile	7.7%	11.8%	6.6%	8.4%	7.1%	10.1%

* KH Mak, Student Health Service, Department of Health, Personal Communication

BMI cut-offs to define overweight and obesity in children and adolescents

Currently there is no universal consensus on a definition or cutoff for defining overweight and obesity in children. Most overweight/obesity definitions are derived from associations between body fat and long term morbidity and mortality. The United States Centers for Disease Control and Prevention defines childhood overweight as BMI between ≥85 and < 95 percentiles and childhood obesity as ≥95 percentiles and the percentiles reference values are sex- and age-specific (Ogden, et al., 2002). These cut-offs value were based on the results of epidemiological studies showing that the risk for eventual morbidity such as cardiovascular diseases and diabetes significantly increase above the 95th centile (Reilly et al., 2003). These criteria were also adopted by many studies (Freedman et al., 2010; Gupta et al., 2011; Moreno, Sarría, Fleta, Rodríguez, & Bueno, 2000; Reilly, Dorosty, & Emmett, 1999; Stettler, Zemel, Kumanyika, & Stallings, 2002) and the 2005/06 Hong Kong Growth Study (So, et al., 2008) to define overweight and obesity. This thesis uses a BMI cutoff between ≥85 and <95 percentiles to define overweight and ≥ 95 percentiles to define obesity (Ogden, et al., 2002).

Disadvantages of using BMI

There are several limitations of using BMI to assess overweight/obesity. Using BMI as an indicator for body fat distribution, to some extent, is not a simple process. It requires a good-quality stadiometer and weighing scale to obtain both BW and BH values for calculation of BMI or using a pre-calculated table to obtain the BMI values. Calculation of BMI may increase the chance of calculation error. The concepts and values of BMI are not easy for children/adolescents and lay people to understand (Lear, 2005).

BMI reflects an individual's BH, body frame size, and fat-free mass in addition to fat mass (Bray, DeLany, Volaufova, Harsha, & Champagne, 2002). BMI assesses the overall status of obesity and it cannot distinguish fat mass from fat-free mass (Committee on Nutrition, 2003; Kelishadi, et al., 2007; Maynard et al., 2001; McCarthy, et al., 2006). Even if two people have the same BMI, their fat mass reserve may be different (McCarthy, Ellis, & Cole, 2003; Sardinha, Going, Teixeira, & Lohman, 1999). In other words, two people with the same amount of fat mass can have quite different BMI values.

BMI is a crude index of body fat measurement (Reilly et al., 2000) and may provide misleading information about the amount of body fat in children/adolescents. BMI gives no indication of body fat distribution in children/adolescents with normal weight and overweight/obese status (Bray, DeLany, Harsha, Volaufova, & Champagne, 2001; Prentice & Jebb, 2001). BMI can be an inaccurate indicator for children/adolescents with normal body fatness because any changes in BMI may be due to changes of skeletal muscle rather than body fat. Measurements of body fat distribution, especially abdominal fat or central or upper body fat, as reflected by WC have been suggested to be associated with an increased risk of cardiometabolic disorders (Hirschler, et al., 2005). The correlation coefficients between BMI and WC were very high; 0.94 for boys and 0.90 for girls (Ochiai et al., 2010).

Waist Circumference

WC was recognized as a strong predictor of intra-abdominal adipose tissue in children/adolescents (Brambilla, et al., 2006; Hsieh, Yoshinaga, & Muto, 2003; Taylor, Jones, Williams, & Goulding, 2000). Intra-abdominal adipose tissue includes abdominal visceral tissue and retroperitoneal adipose tissue. Abdominal visceral tissue is intraperitoneal fat which includes mesenteric and omental fat that drains directly into the portal circulation, while retroperitoneal fat drains into the systemic circulation. (Klein et al. 2007). Abdominal visceral tissue deposition is an independent contributor to an increase of the portal free fatty acid concentration, which can lead to hyperinsulinemia, even in individuals who have a BMI within the normal range (Ruderman & et al., 1998). Abdominal visceral tissue is also suggested as being responsible for the pathogenesis of insulin resistance, dyslipidemia, glucose intolerance, hypertension, and cardiovascular risk (Misra & Vikram, 2003) and is associated with impaired glucose and lipid metabolism (De Simone, Verrotti, & Iughetti, 2001; Fox, Massaro, & Hoffmann, 2007; Matsuzawa, Nakamura, Shimomura, & Kotani, 1995; Montague & O'Rahilly, 2000). Increased abdominal visceral tissue (also called central or abdominal fat) is associated with an increased risk for cardiometabolic disorders (Despres et al., 1990; Klein et al., 2007).

WC has been found to be a strong independent predictor of obesity-related morbidity and mortality in both adults and children/adolescents. WC is strongly correlated with diabetes and cardiovascular disease (de Koning, Merchant, Pogue, & Anand, 2007; Zhu et al., 2002). The Bogalusa Heart Study found that WC was associated with a clustering of CMRFs in children/adolescents aged 5 to 17 years including high triglycerides, high LDL-C, and hyperinsulinemia (Freedman et al., 2007; Hirschler, et al., 2005; Hsieh, et al., 2003) and it could explain up to 64.8% of its variance in children/adolescents aged 7-16 years (Brambilla, et al., 2006).

Definition of overweight and obesity using waist circumference measures

Today, WC charts have been developed in many countries (Eisenmann, 2005; Katzmarzyk, 2004; McCarthy, Jarrett, & Crawley, 2001; Ng et al., 2007; Roswall et al., 2009; Schwandt, Kelishadi, & Haas, 2008; Sung et al., 2007). Maffeis et al. (Maffeis, Pietrobelli, Grezzani, Provera, & Tatò, 2001) found that children with a WC greater than the 90th percentile were at significantly high risk of CMRFs clustering than those children with a WC < 90th percentile. WC ≥ 90 percentile has been used as cutoff to define obesity in children/adolescents and to identify those at high cardiometabolic risk (Cook, Weitzman, Auinger, Nguyen, & Dietz, 2003; Cruz et al., 2004; Ford, 2005; Zimmet et al., 2007). This thesis uses WC ≥ 90 percentile as the cutoff to define obesity in children/adolescents. The Hong Kong Growth Survey 2005/06 WC data was used as reference to identify children/adolescents with WC≥ 90 percentile in this thesis.

Waist circumference measurement protocols

WC is an estimation of abdominal girth and is a surrogate measure of abdominal visceral tissue. Measurement of WC has been recommended for assessing obesity in clinical settings (Alberti, Zimmet, & Shaw, 2006; S. Klein, et al., 2007), as well as in epidemiological studies (Kelishadi, et al., 2007; Yusuf et al., 2005). However, there is no standardized protocol for measuring WC and no consistent anatomical landmark is used to measure WC in different studies. A panel of experts (Ross et al., 2008) suggested using bony landmarks for WC measurement. Using bony landmarks at fixed skeletal sites for WC measurement could provide a guide for training health professionals and lay persons and minimize measurement errors. The measurement guide could ensure higher reliability of WC measures as well as repeated WC measures (Ross, et al., 2008). Experts suggest using either midway between lowest rib and iliac crest as recommended by the World Health Organization (World Health Organization, 2008) or at the superior border of the iliac crest as suggested by National Institutes of Health guidelines (National

Institutes of Health, 2000) for WC measurement consistency. In this thesis, midway between lowest rib and iliac crest, as recommended by the World Health Organization (World Health Organization, 2008), was used by investigators to obtain WC values from the children/adolescents in this thesis. Table 1.3 is a summary of different common WC measurement sites.

Table 1.3 Summary of different commonly used waist circumference measurement sites

Reference	Protocol for measuring waist circumference
Asayama et al (2000)	At the level of the umbilicus
Folsom (2000)	One inch above the umbilicus
National Institutes of Health (2000)	Top of the iliac crest
Turcato et al. (2000)	Minimum abdominal circumference between the xyphoid process and the umbilicus
Bigaard et al. (2005a)	Minimum circumference between the lowest rib and iliac crest but in cases of indeterminable waist narrowing, the midpoint between the lowest rib and iliac crest was used
Buchholz & Bugaresti (2005)	Immediately below the lowest rib
Huang et al. (2005)	The natural waist, at the level of hollow molding of the trunk when the trunk is concaved laterally
Golley, Magarey, Steinbeck, Baur, & Daniels (2006)	Midpoint between the 10th rib and the iliac crest
Katzmarzyk, Craig, & Gauvin, (2007)	At the point of noticeable waist narrowing, but in cases of indeterminable waist narrowing, the lowest rib was used.
Klein, et al. (2007)	Narrowest (minimum) waist circumference
Klein, et al. (2007)	Widest (maximum) waist circumference
WHO (2008)	Midpoint between the lower margin of the last palpable rib and the top of the iliac crest

Strength of using WC as an obesity screening tool in children/adolescents

WC is a simple, accurate, convenient, easy to learn and clinically acceptable surrogate measure of abdominal visceral tissue (Cheng, 2004; S. Klein, et al., 2007; Lear, James, Ko, & Kumanyika, 2009; Revenga-Frauca et al., 2009; Wang, 2003). A larger WC is associated with a higher rate of obesity related cardiometabolic disorder, whereas a smaller WC is more likely to reflect a reduction in abdominal fat mass. This reduction would have a greater clinical implication than reduction of body weight. Studies have found that the reproducibility of WC measurements have demonstrated excellent intra- and inter-observer reliabilities (Chen, Lear, Gao, Frohlich, & Birmingham, 2001; Ross, et al., 2008).

WC correlates closely with BMI and total body fat. Obtaining BMI is more complicated than WC in terms of calculating and explaining BMI scores to patients and public. WC measurement only requires a flexible non-elastic measuring tap which is simple, cheap and portable. Only a few minutes and a tape measure are required to obtain a useful variable cost effectively. However, BMI measurement requires a good-quality stadiometer and weight scale for obtaining BW and BH for the calculation of BMI values.

The prevalence of childhood obesity has increased significantly in the past decades. Childhood obesity has a significant negative impact on cardiovascular and metabolic health in children and their later life (Chen & Wang, 2009; Denzer et al., 2007). A simple, easy-to-learn and convenient screening tool is needed to identify children with overweight/obesity status. WC has been recommended as a screening tool and as a single measure for identifying body fatness in children who are at risk of developing cardiometabolic complications (Kannel et al., 1991; Klein et al., 2004).

Self-report method

Self-report method was used in this thesis to collect Tanner pubertal stage, BW, BH and WC values from the children/adolescents because this method allows for quick, simple and inexpensive data collection where time, cost and privacy are of concern in the large scale sleep study. One study found that SRDBMI and SRWC can satisfactorily assess the prevalence of overweight or obesity and of increased WC in adults (Dekkers, van Wier, Hendriksen, Twisk, & van Mechelen, 2008), and another study noted that SRWC is usable as a proxy for technician-measured WC in regression analyses (Bigaard, Spanggaard, Thomsen, Overvad, & Tjonneland, 2005). Research done on self-reported WC is very limited especially in children/adolescents. It may be due to measured WC itself has not been made popular to define obesity. Nevertheless, self-report method is one of the common data collection methods in the literature, e.g. self-reported pubertal stage, self-reported body weight and body height, and a very limited literature on self-reported waist circumference in adults.

Nonetheless, self-reported data are subject to measurement errors including bias and variance. For example, a study comparing self-reported and measured BW and BH found that subjects tend to overestimate their BH but underestimate their BW (Danubio, Miranda, Vinciguerra, Vecchi, & Rufo, 2008), leading to a systematic error. The direction of this bias likely reflects what is perceived to be socially desirable in the real world.

Puberty, obesity and cardiometabolic risk

Pubertal development plays an important role in the growth and development of children/adolescents. Puberty is a process of sexual maturation manifesting as a complex physiological process resulting in changes in body composition associated with hormonal changes that influence growth and development of children/adolescents. Overweight/obese children/adolescents face challenges during growth and development and during sexual maturation because the significant increased adipose tissue produces endocrinologically active substances. Overweight/obesity is associated with abnormal insulin resistance in children/adolescents due to increased adipose tissue (Chiarelli & Marcovecchio, 2008). Pre-pubertal obese children have also been found to have insulin resistance (Caprio, Bronson, Sherwin, Rife, & Tamborlane, 1996). Insulin resistance is "a state in which a given concentration of insulin is associated with a subnormal glucose response" (Moller & Flier, 1991) and is characterized by "a decrease in the ability of insulin to stimulate the use of glucose by muscles and adipose tissue and to suppress hepatic glucose production and output" (Matthaei, Stumvoll, Kellerer, & Haring, 2000). Overweight/obese children/adolescents have a significantly increased insulin resistance particularly in middle puberty, approximating to Tanner stages 2, 3 and 4 because of increased overall and visceral adiposity (Boyko, Fujimoto, Leonetti, & Newell-Morris, 2000). Subsequently pancreatic ß-cells are unable to compensate adequately for this insulin resistance (Kahn, 2001) leading to metabolic abnormalities and type 2 diabetes (Caceres, Teran, Rodriguez, & Medina, 2008; Caprio, et al., 1996; Flegal, Ogden, Wei, Kuczmarski, & Johnson, 2001; Wang, Rimm, Stampfer, Willett, & Hu, 2005). Studies have found that insulin resistance was associated with hyperlipidaemia in children/adolescents (Holst-Schumacher, Monge-Rojas, & Barrantes-Santamaría, 2009; Zachurzok-Buczyńska, Klimek, Firek-Pedras, & Małecka-Tendera, 2011) resulting in increased risk of cardiovascular disease (Weiss & Kaufman, 2008). Puberty has also been found to be positively associated with increased blood pressure (Chen & Wang, 2009). Overweight/obesity in children/adolescents has accelerated growth and pubertal maturation (Wang, 2002). The stage of puberty may thus have an impact on metabolic outcomes, particularly in overweight/obese children/adolescents.

Summary

In summary, BMI and WC are the most widely used anthropometric measures in clinical, community and research settings. BMI and WC are simple, accessible, low cost and practical tools for identifying overweight and obesity and have been useful predictors of metabolic and cardiovascular morbidity and mortality (Freedman, et al., 2007; Kahn, Imperatore, & Cheng, 2005; Maffeis, et al., 2001; McCarthy & Ashwell, 2006). Self-reported anthropometric measures for identifying overweight/obesity have been used elsewhere, either in adults or in children/adolescents. To the best of our knowledge, no study has been has been conducted to assess the agreement between measured and self-reported anthropometric measures in terms of BW, BH and WC and the diagnostic ability of these measures to identify children/adolescents with overweight/obesity status and CMRFs clustering in Hong Kong Chinese children/adolescents.

Although puberty is one of the important factors to consider when assessing metabolic parameters in children/adolescents, no known study has been done on the association between pubertal stages and CMRFs clustering in Hong Kong Chinese children. The research questions, aims and objectives of this study are described in the following sections.

Research questions, aims and objectives of the study

1) Can SRDBMI and SRWC be used as screening tools for identifying overweight/obesity status and CMRFs in Hong Kong Chinese children/adolescents?

2) Is there an association between a clustering of CMRFs and pubertal stage?

3) Do we need to account for puberty when assessing overweight/obesity and CMRFs?

Aims of the study

The aims of the study were two fold. The first aim was to identify simple self-reported anthropometric screening tools to identify overweight and obese status in Hong Kong Chinese children. The second aim was to investigate the effect of pubertal stage on the prediction of CMRFs clustering in Hong Kong Chinese children/adolescents.

Objectives of the study were to:

1) Assess the performance of Tanner pubertal questionnaire with Chinese text and Chinese Pubertal Development Scale between assessor's visual depict physical examination and the children/adolescents' self-reported scores

2) Assess the agreement of BW and BH between self-reported and measured values;

3) Assess the agreement of WC between self-reported and measured values;

4) Examine the diagnostic ability of SRDBMI for classifying children/adolescents with overweight and obesity status and CMRFs clustering;

5) Examine the diagnostic ability of SRWC in classifying children/adolescents with overweight and obesity status and CMRFs clustering;

6) Investigate the association between self-reported pubertal stage and CMRFs;

7) Investigate the effect of pubertal stage on the prediction of CMRFs by BMI and WC.

CHAPTER 2

ASSESSMENT OF SELF-REPORTED PUBERTAL STAGE

Preface

This Chapter presents the children/adolescents' abilities to assess their own pubertal stage using two Chinese pubertal assessment questionnaires: line-drawing Tanner pubertal questionnaire with Chinese text and Pubertal Development Scale (PDS). The children/adolescents could be able to assess their own pubertal stage approximately and consistently with the assessors' rating results. The papers resulting from this chapter were published in peer review journals. The paper entitled "Reliability of pubertal self-assessment in Hong Kong Chinese children" was published in the Journal of Paediatrics and other paper entitled "Measurement of pubertal status with a Chinese self-reported Pubertal Development Scale" was published in the Child Health and the Maternal and Child Health Journal.

INTRODUCTION

Puberty is a significant period of physiological changes and sexual maturation transitioning from childhood to adolescence. Sexual maturation begins with the pulsatile release of gonadotropin-releasing hormones to stimulate the production of estrogen and androgen which are responsible for the development of secondary sexual characteristics, namely breast development and menstruation in girls and beard, penis and testes development in boys. Physiological changes include a growth spurt, with an increase in height, bone mass, fat mass and muscle mass, together with development of body hair and body odour (Marshall & Tanner, 1968, 1969). The timing of the onset of normal pubertal development and sexual maturation rates varies across a wide range of ages; from about 10 to 16 years old (Marshall & Tanner, 1968, 1969; Nottelmann et al., 1987; Tanner, 1962).

Sexual maturation may influence many aspects of the adolescent development, from cognitive performance, self-perception, and socio-sexual behaviour to risky behaviours, delinquency (Sarigiani, Ryan, & Petersen, 1999) and psychopathology (Graber, Lewinsohn, Seeley, & Brooks-Gunn, 1997; Graber, Seeley, Brooks-Gunn, & Lewinsohn, 2004; Hayward et al., 1997). Behavioural changes that occur during adolescence have been found to have a greater correlation with sexual maturation status than with chronologic age (Ellis, 2004; Lam, Shi, Ho, Stewart, & Fan, 2002).

Puberty is also associated with metabolic and hormonal changes. Increases in pubertal growth hormone is associated with a decreased insulin-sensitivity and an increased insulin secretion and resistance from Tanner pubertal stage II to IV, followed by a return to approximate prepubertal levels by the end of puberty. The transient changes in insulin levels are a normal physiological development during puberty (Bloch, Clemons, & Sperling, 1987; Goran & Gower, 2001; Moran et al., 1999; Moran et al., 2002; Travers, Jeffers, Bloch, Hill, & Eckel, 1995). Hence, when identifying children/adolescents who are at risk of having persistent abnormal hyperinsulinemia and insulin resistance in clinical care and epidemiological studies, it is important to assess sexual maturation status of children/adolescents as different Tanner stages manifest different insulin sensitivity levels and insulin resistance.

Sexual maturation status can be assessed by hormonal assays and physical assessment. Hormones involved in pubertal development are gonadotrophinreleasing hormone which simulates release of follicle-stimulating hormone and luteinizing hormone. The follicle-stimulating hormone and luteinizing hormone then stimulate the gonads (ovaries or testes) to produce more of the sex steroids including estrogen and progesterone in females and testosterone in males and androgens in both females and males. However, daytime levels of these hormones are low in the early stages of puberty. A single hormonal assay may not reflect true levels because of the pulsatile nature of gonadotrophin release (Bridges, Matthews, Hindmarsh, & Brook, 1994). Moreover, the use of hormonal assays may not be widely available and expensive. Due to such limitations of hormonal assays, questionnaires such as the self rating Tanner Pubertal Questionnaire and Pubertal Development Scale may be preferable for data collection in large epidemiological studies and community settings.

Tanner pubertal questionnaire

The Tanner Sexual Maturation Scale (Marshall & Tanner, 1968, 1969) has been a reference method for the assessment of sexual maturation status in children/adolescents. Nevertheless, use of this scale requires children/adolescents to disrobe for physical assessment by medical/health professionals. Children/adolescents may be reluctant to be examined in the nude and involvement of medical/health professionals may also make this assessment method unsuitable for large scale epidemiological studies. To avoid embarrassment and to increase participation rate, the Tanner standard photographs (Marshall & Tanner, 1968, 1969) and gender-specific line drawings (Morris & Udry, 1980) pubertal self-assessment questionnaires were developed to assess sexual maturation status of children/adolescents. The questionnaire illustrates 5 stages of pubertal development of children/adolescents including female breast, male genitalia and pubic hair in both genders with a brief description. Previous studies showed that children/adolescents were able to assess their sexual maturation status using Tanner pubertal questionnaire (Chan et al., 2008; Morris & Udry, 1980; Norris & Richter, 2005; Taylor et al., 2001), although some negative results have also been reported (Desmangles, Lappe, Lipaczewski, & Haynatzki, 2006; Hergenroeder, Hill, Wong, Sangi-Haghpeykar, & Taylor, 1999; Wu, Lee, & Wu, 1993).

Pubertal Developmental Scale

However, using the Tanner pubertal questionnaire with its pictures or drawings of naked males and females, could raise objections from school principals and parents (Bond et al., 2006; Petersen, Crockett, Richards, & Boxer, 1988). It is also possible that completion of the questionnaire in classroom could cause embarrassment for some students and this might deflect attention from the questionnaire itself. In response to such resistance by schools and parents, and to improve participation rates in studies involving pubertal assessment of children/adolescents, a Pubertal Developmental Scale (PDS) (Petersen, et al., 1988) has been developed. The scale consists of five questions, with responses based on a four point scale. The PDS enables children/adolescents to rate their own sexual maturation status and has been shown to be comparable to the other self-reported sexual maturation status tools (Bond, et al., 2006; Brooks-Gunn, Warren, Rosso, & Gargiulo, 1987; Carskadon & Acebo, 1993; Schmitz et al., 2004). Two studies have found that children were able to use PDS to report their pubertal status consistently with the self-assessment Tanner Pubertal questionnaire results (Bond, et al., 2006; Carskadon & Acebo, 1993), and parents and teachers' report on the students' sexual maturation status (Carskadon & Acebo, 1993), but without physical assessment by raters for comparison. The PDS has also been used for mothers to report their daughters' pubertal development in a longitudinal study (Baker, Birch, Trost, & Davison, 2007; Davison, Werder, Trost, Baker, & Birch, 2007). Two further studies (Brooks-Gunn, et al., 1987; Schmitz, et al., 2004) comparing the agreement between the self-reported PDS against physician rating using Tanner pubertal assessment questionnaire have shown fair to moderate agreement. Both studies concluded that PDS was a useful alternative for broad estimation of children's pubertal stages in epidemiological studies.

Aims of the study

To the best of our knowledge, no study has assessed the performance of Tanner pubertal self-reported questionnaire and self-reported PDS in Hong Kong Chinese children. Therefore our study was designed to assess the performance of a Chinese version line-drawing Tanner pubertal self-reported questionnaire (Appendix 2.1 & 2.2) and self-reported PDS (Appendix 2.5 & 2.6) using visual depiction sexual maturation examination by a same gender rater in Hong Kong Chinese children.

Objectives of the study

1) Assess the performance of Tanner pubertal questionnaire with Chinese text between assessor's visual depict physical examination and the children/adolescents' self-reported scores;
2) Assess the performance of Chinese Pubertal Development Scale between assessor's visual depict physical examination and the children/adolescents' self-reported scores;

METHODS

The children/adolescents were drawn from a convenience sample. Sample size estimation was based on previous self-reported of sexual maturation status research. The children/adolescents aged between 8 to 18 years were recruited from school settings.

Study population

Sample size of the Tanner pubertal questionnaire with Chinese text

A total of 354 students including 172 boys and 182 girls were recruited from one primary (59 boys and 63 girls) school and 2 secondary schools (113 boys and 119 girls) for the study of the Tanner pubertal questionnaire.

Sample size of the Chinese version Pubertal Developmental Scale

The same group of students were also asked to assess their pubertal stage using a Chinese PDS. Of these 354 students, 290 students including 59 boys and 63 girls from one primary school and 70 boys and 98 girls from one secondary school responded to the PDS questionnaire.

Study protocol

Content validity of the Chinese version line-drawing Tanner pubertal questionnaire and PDS was done by a paediatrician, an endocrinologist and four students, that is a pair of male and female students aged 11 years studying in grade 6 and another pair aged 12 years studying in grade 7, for content readability and comprehension. The two students who studied in grade 6 required clarification of some terms such as "areola", "menstruation", "scrotum", "testes", "deepening-voice" and "grow hair on your face". Therefore during administration of the questionnaire, questions were read aloud to those children who studied in grade 6 or below with consistent explanations of the various terms and to any students who asked for clarification. Children/adolescents were also given an explanation of these terms if they requested for this information. No major changes were done to the wording or phrasing of the questionnaires.

Since data collection was conducted in school settings, the research staff wore hospital uniforms so as to look more professional, increase trust between the children/adolescents and research staff and ultimately facilitate data collection. Children/adolescents were given the Chinese versions of the Tanner pubertal questionnaires, followed by the PDS to fill out, before undergoing visual depiction physical examination by a same gender rater who was experienced in Tanner staging in a private room. The raters were unaware of the results of the two self-reported questionnaires.

Instruments

Two instruments were used in this study; line-drawing Tanner pubertal questionnaire with Chinese text and Chinese self-reported PDS were described as follows:

The line-drawing Tanner pubertal questionnaire

A line-drawing Tanner pubertal questionnaire (Morris & Udry, 1980) with Chinese text was used to rate the children/adolescents' sexual maturation status by trained raters and by the children/adolescents themselves. The questionnaires have illustrations of five stages of female breast, male genitalia development and pubic hair growth in both genders, together with brief written descriptions in Chinese.

The Chinese version Pubertal Developmental Scale

The Chinese version PDS consists of five items: age at menarche, breast growth in girls, deepening-voice and facial hair growth in boys, body hair growth, and growth spurt and skin changes, especially pimples in both genders. Children/adolescents were asked to respond to a 4-point scale; "not yet started (1 point)", "barely started (2 points)", "definitely started (3 points)" or "seems completed (4 points)". Answering "I don't know" was considered as missing. Menarche was coded dichotomously; either no (0 point) or yes (1 point).

Table 2.4 Computation of puberty category scores using the algorithm developed by Crockett

		Boys	Girls
Tanner stage		Totaling body hair growth, voice-deepening, and facial hair growth	Totaling body hair growth, breast development, and menarche
1	Prepubertal	3	2 and no menarche
2	Early Pubertal	4 or 5 (no 3-point responses)	3 and no menarche
3	Midpubertal	6, 7, or 8 (no 4-points)	> 3 and no menarche
4	Late pubertal	9-11	<= 7 and menarche
5	Postpubertal	12	8 and menarche

For the purposes of comparison with the Tanner stages, the three salient sexual maturation characteristics of the PDS - menarche, breast and body hair growth in girls, and deepening-voice, body hair and facial hair growth in boys - were computed using the algorithm developed by Crockett (Petersen, et al., 1988) to generate the puberty category scores. The puberty category scores were used to categorize the children/adolescents into one of the five pubertal development stages (Table 2.4). The scores of the two items of the Tanner questionnaire in each gender; breast Tanner (BT), male genitalia Tanner (GT), pubic hair (PH) in both genders, were averaged and then rounded up to the highest pubertal stage to avoid underestimating the sexual maturation status of children/adolescents. The roundup pubertal stage was called the Tanner derived composite stage (TDCS) which was used for comparing the agreements with the puberty category scores.

Anthropometric measures

Students were measured for height and weight, WC and hip circumference using standard techniques and with the children/adolescents standing without shoes and lightly clothed. WC was measured midway between the lowest rib and the superior border of the iliac crest at minimal respiration. Hip circumference was taken at maximal protrusion of the buttocks. The circumferences were given as the mean of two measurements to the nearest 0.1 cm. BMI was calculated as weight/height^2 (kg/m^2).

Ethics Committee approval

This study was approved by the Joint Chinese University of Hong Kong - New Territories East Cluster Clinical Research Ethics Committee. Consent for participating in the study were sought from both parents and students, with letters explaining the purpose and procedure of data collection sent to all students and parents via the schools. Parents and students were informed that participation in the study was voluntary and they could withdraw from the study anytime without penalty.

Statistical analysis

Statistical analyses were performed using SPSS version 16, including means [± standard deviation (SD)], frequencies, and accuracy rates. The corrected-item total correlations were used to indicate the degree to which each item of PDS correlates with the total score. If the value is less than 0.3, it indicates that the item is not measuring the same construct of the scale as a whole. Cronbach's alpha coefficients were used to measure the internal consistency and the scale reliability of the PDS.

The StatXact 8 software (Cytel Statistical Software & Services) was used to compute the inter-rater agreements using the weighted kappa (WK) statistic with 95% confidence interval (95% CI). The children/adolescents' self-reported versus raters' assessment was evaluated by accuracy rates and by weighted kappa statistic for inter-rater agreement. The weighted kappa statistic is an agreement statistic for ordered categories and the proportion of weighted agreement is corrected for chance (Fleiss & Cohen, 1973). The weighted kappa statistic allows for differential weighting of disagreement (Cohen, 1968). That is when the number of categories increases, the weighted kappa value will decrease as there is more chance for disagreement with more categories. Fleiss (Fleiss, 1981) suggested a quadratic weighting (the square terms) gives high weights to responses that differ by one category and low weights if the responses differ by two and three categories. No weight is given to responses differing by four categories. Based on the principles of quadratic weighting, two Tanner stages were combined for analysis using cross tabulations if one cell in one of the stages is empty. Kappa 'Benchmarks'(Landis & Koch, 1977) of the strength of agreement are as follows: < 0.00=poor; 0.00-0.20=slight; 0.21-0.40=fair; 0.41-0.60=moderate; 0.61-0.80=substantial; >0.8=almost perfect.

Kendall's τ-b correlation coefficient was also used to measure the strength of the cross tabulations of breast, male genitalia and pubic hair Tanner stages. It was also used to present the strength of association between the PDS and Tanner pubertal questionnaire. Kendall's τ-b correlation is based on the ranking of data measured at the ordinal level correlation coefficients. Values range from -1 (no association) to +1 (the theoretical maximum possible association) and increasing values imply increasing agreement between the rankings. A value of zero means no association.

RESULTS

The results of the two studies were reported individually in the following sections. The results of the self-reported Tanner pubertal questionnaire with Chinese text were reported first followed by the self-reported PDS.

Tanner pubertal questionnaire with Chinese text

Characteristics of the participants

The mean (± standard deviation, SD) of chronological age was 12.2(1.7) years for boys and 12.4(1.8) years for girls. The mean (± SD) BMI for boys and girls was 19(3.3) and 18.8(3.4) kg/m^2 respectively (Table 2.1). According to the international BMI cut-offs (Cole, et al., 2000), 25(14%) girls and 35(20%) boys were categorized as overweight or obese. This proportion was similar to the 2005/6 Hong Kong study that showed 12.5% girls and 20.9% boys were overweight or obese using these same cut-offs (So, et al., 2008).

Table 2.1 Characteristics of the study population for assessing the performance of self-reported Tanner pubertal questionnaire

	Boys (n=172)			Girls (n=182)		
	Mean(±SD)	**Min**	**Max**	**Mean(±SD)**	**Min**	**Max**
Age (years)	12.2(1.7)	8.2	17.5	12.4(1.8)	8.2	18
BMI (kg/m^2)	19(3.3)	13.2	30	18.8(3.4)	13.4	31.6
Body weight (kg)	44.2(12.2)	22.7	87.6	43.2(10.7)	23.2	79.3
Body height (m)	1.5(0.1)	1.3	1.8	1.5(0.1)	1.2	1.7
Waist circumference (cm)	67.1(9.1)	48.50	95.2	64.6(8.8)	47	96
Hip circumference (cm)	81.6(8.3)	64.50	111	82.5(8.9)	62	108

SD, standard deviation; Min, minimum, Max, maximum

Self-reported breast development in girls

Of all girls (n=182), 102(56%) showed complete agreement with the rater in estimating their breast Tanner (BT) stage. The highest percentage of complete agreement (19%) was observed in BT2. The highest percentage of disagreement

(22%) was noted in BT3. Forty-one (23%) and 3(2%) girls overestimated 1 and 2 BT stages respectively; 35(19%) and 1(0.6%) girls underestimated 1 and 2 BT stages respectively (Table 2.2a).

The quadratic weighted kappa statistic measure of agreement for BT staging was 0.72 ($p<0.0001$, 95% CI 0.66, 0.79). Moderate correlation (Kendall's τ-b=0.64; $p<0.01$) between girls' self assessments and rater's assessments of BT staging was found (Table 2.3). The mean (±SD) chronological age for BT stage 1, 2, 3, 4 and 5 was 11.6(1.5); 11.8(1.6); 12.8(1.6); 13.6(1.6) and 16.9(1) respectively.

Self-reported pubic hair development in girls

Among 182 girls, 108 (59%) completely agreed with the examiner in assessing their pubic hair (PH) Tanner stages. The highest percentage of complete agreement (28%) was found in PH1. The highest percentage of disagreement (18%) was noted in PH3; 25(14%) and 2(1%) girls overestimated 1 and 2 PH Tanner stages; 42(23%) and 5(3%) girls underestimated 1 and 2 PH Tanner stages respectively (Table 2.2a).

The quadratic weighted kappa statistic measure of agreement of all girls for PH staging was 0.83($p<0.0001$, 95% CI 0.78, 0.87). Correlation between girls' self-reported and rater's assessments was moderately high (Kendall's τ-b=0.76; $p<0.0001$) (Table 2.3). The mean (±SD) chronological age for PH Tanner stage 1, 2, 3, 4 and 5 was 10.9(1.4); 12.5(1); 12.8(1.2); 13.6(1.6) and 15.8(1.6) years respectively.

Self-reported genital development in boys

Of the entire group of boys, 84(49%) have shown complete agreement with the rater in estimating their genitalia Tanner (GT) stage. The highest percentage of complete agreement (23%) was found in GT2. The highest percentage of disagreement (20%) was noted in GT3. Thirty-seven (22%) and 1(0.6%) boys overestimated 1 and 2 Tanner stages respectively. Forty-seven (27%), 2(1%) and 1(0.6%) boys underestimated 1, 2 and 3 male GT stages respectively (Table 2.2b). The quadratic weighted kappa statistic measure of agreement for GT staging was 0.58($p<0.0001$, 95% CI 0.48, 0.68). Moderate correlation (Kendall's τ-b=0.52; $p<0.0001$) between boys' self assessments and rater's assessments of GT staging was found (Table 2.3). The mean (±SD) chronological age for male genitalia Tanner stage 1, 2, 3, 4 was 10.8(1.6); 11.8(1.1); 13.1(1.2); 16(1.3) respectively. Only one boy aged 16 years was categorized as male genitalia Tanner stage 5.

Table 2.2a Cross-tabulation between girls' self-reported and rater's assessment of breast and pubic hair stages

Rater's assessment	Girls' self-reported					
	1	**2**	**3**	**4**	**5**	**Total**
Breast stages						
1	**10**	7	0	0	0	**17**
2	2	**34**	11	2	0	**49**
3	0	16	**31**	23	1	**71**
4	0	1	14	**26**	0	**41**
5	0	0	0	3	**1**	**4**
Pubic hair stages						
1	**50**	4	0	0	0	**54**
2	7	**17**	3	1	0	**28**
3	1	17	**19**	13	1	**51**
4	0	3	16	**20**	5	**44**
5	0	0	1	2	**2**	**5**

Table 2.2b Cross-tabulation between boys' self-reported and rater's assessment of genital and pubic hair stages

Rater's assessment	Boys' self-reported					
	1	**2**	**3**	**4**	**5**	**Total**
Genital stages						
1	**17**	18	1	0	0	**36**
2	19	**39**	10	0	0	**68**
3	2	24	**25**	9	0	**60**
4	1	0	3	**3**	0	**7**
5	0	0	0	1	0	**1**
Pubic hair stages						
1	**74**	23	4	0	0	**101**
2	1	**18**	8	1	0	**28**
3	0	6	**12**	9	0	**27**
4	0	1	4	**10**	0	**15**
5	0	0	0	1	0	**1**

Table 2.3 Summary of studies on agreement of pubertal self-reported and rater assessments

Studies using line drawings	Sample sizes	Statistical methods	Breast Tanner	Female Pubic Hair	Male Genitalia	Male Pubic Hair
Morris & Udry (1980)	Female (n=47) Male (n=48)	Pearson correlation coefficient	0.63	0.81	0.59	0.63
Wu, Schreiber, Klementowicz, Biro, & Wright (2001)	White female (n=174) Black female (n=130)	Kappa coefficient (Adjusted age)	0.32-0.51	0.36-0.55	not applicable	not applicable
Taylor, Whincup, Hindmarsh, Lampe, Odoki, & Cook (2001)	Female (n=41) Male (n=62)	Weighted kappa coefficient	0.43 (95% CI 0.18, 0.68)	0.60 (95% CI 0.31, 0.89)	0.51 (95% CI 0.29, 0.73)	0.75 (95% CI 0.51, 0.99)
Norris & Richer (2005)	Female (n= 90) Male (n= 92)	Kappa coefficient	0.81	0.71	0.60	0.63
Present study (2007)	Female (n=182) Male (n=172)	Weighted kappa coefficient	0.72*** (95% CI 0.66, 0.79)	0.83*** (95% CI 0.78, 0.87)	0.58*** (95% CI 0.48, 0.68)	0.80*** (95% CI 0.74, 0.86)
		Kendall'sτ-b correlation	0.64**	0.76**	0.52**	0.75**
Studies using standard pictures						
Duke, Litt, & Gross (1980)	Female (n=43) Male (n=23)	Kappa coefficient	0.81	0.91	0.88	
Neinstein (1982)	Female (n= 22) Male (n= 22)	Spearman correlation	0.87	0.86	0.72	0.69
Wacharasindhu, Pri-Ngam, & Kongchonark (2002)	Female (n=100) Male (n=94)	Weighted kappa coefficient	0.76	0.79	0.73	0.59

**p< 0.01 level (2-tailed). ***p< 0.0001 level (2-tailed). CI, confidence Interval.

Self-reported pubic hair development in boys

Among 172 boys, 114(66%) completely agreed with the rater in assessing their pubic hair (PH) stages. Both the highest percentage of complete agreement (43%) and disagreement (16%) were observed in PH1. Of all boys, 40(23%) and 5(3%) boys overestimated 1 and 2 PH Tanner stages; 12(7%) and 1(0.6%) boys underestimated 1 and 2 PH Tanner stages respectively (Table 2.2b).

The quadratic weighted kappa statistic measure of agreement for PH Tanner staging was 0.80($p<0.0001$ 95% CI 0.74, 0.86). Correlation between boys' self-reported and rater's assessments of PH Tanner staging was moderately high (Kendall's τ-b=0.75; $p<0.0001$) (Table 2.3). The mean (±SD) chronological age for PH Tanner stage 1, 2, 3, 4 was 11.4(1.4); 12.4(0.8); 13.2(1.2); 15.2(1.2) respectively. Only one boy aged 17 years was categorized as PH Tanner stage 5.

Self-reported Pubertal Developmental Scale (PDS)

Characteristics of study population

The mean (±SD) chronological age was 12 (2) years for boys and 12.4 (1.9) years for girls. The mean (±SD) BMI for boys and girls was 19 (3.3) and 18.9 (3.4) kg/m^2 respectively (Table 2.5). Of the entire group of children/adolescents, 21 girls (13%) and 28 boys (21.7%) were categorized as overweight or obese according to the international BMI cutoffs (Cole, et al., 2000).

Table 2.5 Characteristics of the study population assessing the performance of self-reported Pubertal Developmental Scale (PDS)

	Boys (n=129)			**Girls (n=161)**		
	Mean(±SD)	Min	Max	Mean(±SD)	Min	Max
Age (years)	12.1 (±1.97)	8.2	17.5	12.4(±1.92)	8.2	18.0
BMI (kg/m²)	19.1(±3.32)	13.2	28.5	18.9(±3.38)	13.9	31.6
Body weight (kg)	44.4(±12.66)	22.7	87.6	43.2(±10.85)	23.2	79.3
Body height (m)	1.5(±0.13)	1.3	1.8	1.5(±.095)	1.2	1.7
Waist circumference (cm)	67.1(±9.17)	48.5	94.0	64.6(±9.10)	47.0	96.0
Hip circumference (cm)	81.3(±8.40)	64.5	106	82.5(±9.07)	62	108

The internal consistency of the PDS

The corrected-item total correlations ranged from 0.52 to 0.69 for girls and 0.33 to 0.47 for boys. The Cronbach's coefficient alpha of the PDS was 0.80 for girls and 0.66 for boys. When excluding growth height and skin changes, the corrected-item total correlations were moderately high (0.67, 0.65, 0.56) for girls and fair to moderate (0.33, 0.39, 0.42) for boys. The Cronbach's alpha was 0.75 for girls and 0.56 for boys. The results of the corrected-item total correlations and the Cronbach's alpha indicated that the internal consistency of the PDS measured pubertal growth of children as a whole. The children were consistent in their reports of pubertal changes across the item characteristics.

Pubertal assessment in girls

In general, most agreements and correlations between rater's assessment and girls' self-report corresponded from moderately high to substantial. Of the 161 girls, substantial agreements were found between rater and girls for TDCS [Weighted Kappa 0.79 (0.74, 0.84); Kendallτ-b 0.74 (0.68, 0.79)] and BT [Weighted Kappa 0.74 (0.67, 0.81); Kendallτ-b 0.67 (0.60, 0.75)] but almost perfect agreement for PH [Weighted Kappa 0.83 (0.78, 0.88); Kendallτ-b 0.77 (0.72, 0.83)]. The agreement between rater's TDCS and girls' puberty category scores was moderately high [Weighted Kappa 0.57 (0.44, 0.71); Kendallτ-b 0.60 (0.51, 0.69)], and girls' self-reported TDCS and puberty category scores was substantial [Weighted Kappa 0.66 (0.56, 0.77); Kendallτ-b 0.65 (0.57, 0.73)].

The correlation coefficients between girls' self-reported PDS and rater's TDCS [Kendallτ-b 0.61 (0.54, 0.69)], and girls' self-reported PDS and TDCS [Kendallτ-b 0.62 (0.55, 0.69)] were substantial. Table 2.6 displays the correlation coefficients of the individual items between assessor rated Tanner pubertal assessment questionnaire and girls' self-reported PDS. Results of the strength of the relationship were significant with moderately high to substantial correlation coefficients between items.

Table 2.6 Kendall's τ-b correlation coefficient between rater's assessment and children's self-reported of the individual items of the Tanner scale and the PDS (95% CI)

	Girls' self-reported PDS		Boys' self-reported PDS	
	Breast growth	Body hair	The composited item of deepening-voice & facial hair growth	Body hair
Rater's assessment of BT	0.50(**) (0.38, 0.61)			
Rater's assessment of GT			0.45(**) (0.33, 0.58)	
Rater's assessment of PH		0.61(**) (0.51, 0.71)		0.52(**) (0.38, 0.65)
Children's self-reported PH		0.59(**) (0.48 .69)		0.48(**) (0.34, 0.61)
Girl's self-reported BT	0.60(**) (0.51, 0.70)			
Boy's self-reported GT			0.46(**) (0.33, 0.59)	

Correlation is significant at the 0.01 level (2-tailed) (**)
Note: Two salient sexual characteristics, items of deepen voice and moustache in boys were composited, averaged and rounded up to the highest stage which is used for computation of correlation coefficient.

Of all girls, the complete agreement between rater's TDCS and puberty category scores was 40.4%. The highest agreement (18.6%) and disagreement (27.3%) were found in late pubertal (stage 4) and midpubertal (stage 3) respectively. Sixty-two (38.5%) and 12 (7.5%) girls overestimated 1 and 2 TDCS and 20 (12.4%) girls underestimated 1 TDCS (Table 2.7a).

Table 2.7a Crosstabulation of the agreement (percent of agreement) between rater's Tanner Derived Composition Stage (TDCS), girls' TDCS and girls' Pubertal Category Scores

		Girls' Pubertal Category Scores						
	Tanner stage	Missing/ don't	**1**	**2**	**3**	**4**	**5**	**Total**
Rater's TDCS	**1**	0	**7**(4.3)	6	2	0	0	15
	2	0	6	**19**(11.8)	16	10	0	51
	3	1	0	4	**8**(5)	39	0	52
	4	0	0	0	3	**30**(18.6)	1	34
	5	1	0	0	0	7	**1**(0.6)	9
Girls TDCS	**1**	0	**6**(3.7)	4	0	0	0	10
	2	0	7	**22**(13.7)	14	7	0	50
	3	1	0	3	**12**(7.5)	31	0	47
	4	1	0	0	3	**44**(27.3)	1	49
	5	0	0	0	0	4	**1**(0.6)	5
		2	13	29	29	86	2	161

Note: The agreement between rater's TDCS and girls' PCS: WK 0.57, 95% CI(0.44, 0.71)
The agreement between girls' TDCS and girls' PCS: WK 0.66, 95% CI(0.56, 0.77)

Self-reported menarche

Of the entire group of girls, 98(54%) reported that they had reached menarche; the age ranged from 10 to 13 years. Fifty percent of girls recalled having reached menarche at 11 years old. All were rated within BT stage 3 to 4.

Pubertal assessment in boys

Of the 129 boys, the agreements and correlation coefficients between rater and boys corresponded from moderate to substantial. Substantial agreements were found between rater and boys for TDCS [Weighted Kappa 0.74 (0.66, 0.82); Kendall τ-b 0.64 (0.54, 0.73)]; GT [Weighted Kappa 0.65 (0.54, 0.76); Kendallτ-b 0.58 (0.48, 0.68)] and PH [Weighted Kappa 0.80 (0.74, 0.87); Kendallτ-b 0.76 (0.70, 0.82)]. Moderately high agreements were found between rater's TDCS and boys' puberty category scores [Weighted Kappa 0.58 (0.47, 0.69), Kendall τ-b 0.50 (0.38, 0.62)], and boys' self-reported TDCS and puberty category scores [Weighted Kappa 0.58 (0.44, 0.71), Kendall τ-b 0.53 (0.41, 0.65)].

Moderate correlations were obtained between the boys' self-reported PDS and the rater's TDCS [Kendall τ-b 0.49 (0.38, 0.61)], and the boys' self-reported PDS and TDCS [Kendall τ-b 0.53 (0.42, 0.64)]. For comparing the items between GT and PDS, two male salient sexual characteristics - voice-deepening and facial hair growth of the PDS - were combined, averaged and rounded up to the highest stage. This PDS composite item was then used to compute the correlation between the rater's assessment of GT and boys' self-reported GT. Table 2.6 shows the correlation coefficients of the individual items between Tanner scale and boys' self-reported PDS. Results of the strength of the relationship were significant with moderate correlation coefficients between items.

The complete agreement between rater's TDCS and boys' puberty category scores for boys was 38.8%. Both the highest complete agreement (15.5%) and disagreement (24.9%) were observed in TDCS stage II. Eighteen (14%) and 3 (2.3%) boys overestimated 1 and 2 TDCS, 48 (37.2%) and 3 (2.3%) boys underestimated 1 and 2 TDCS respectively (Table 2.7b).

Table 2.7b Crosstabulation of the agreement (percent of agreement) between rater's Tanner Derived Composition Stage (TDCS), boys' TDCS and boys' Pubertal Category Scores

	Tanner stage	Boys' Pubertal Category Scores						
		Missing/ don't know	**1**	**2**	**3**	**4**	**5**	**Total**
Rater's TDCS	**1**	3	**15** (11.6)	10	3	0	0	31
	2	3	22	**20**(15.5)	7	0	0	52
	3	1	3	14	**10**(7.8)	1	0	29
	4	0	0	0	10	**5**(3.9)	0	15
	5	0	0	0	0	2	**0**(0)	2
Boys' TDCS	**1**	3	**20(15.5)**	5	2	0	0	30
	2	3	15	**26(20.2)**	9	0	0	53
	3	0	5	12	**7(5.4)**	0	0	24
	4	1	0	1	12	**8(6.2)**	0	22
	5	0	0	0	0	0	**0(0)**	0
		7	40	44	30	8	0	129

Note: The agreement between rater's TDCS and boys' puberty category scores: Weighted Kappa 0.58 95% CI (0.47, 0.69)

The agreement between boys' TDCS and boys' puberty category scores: Weighted Kappa 0.58, 95% CI (0.44 0.71)

DISCUSSION

Self-reported Tanner pubertal questionnaire

We evaluated the performance of the self-reported Tanner pubertal questionnaire in Hong Kong Chinese children. Our results suggested most children/adolescents were capable of identifying their own sexual maturation status approximate to the rater's assessments resulting in a moderate to almost perfect agreement. The study results are supported by many studies using line drawings (Morris & Udry, 1980; Norris & Richter, 2005; Taylor, et al., 2001; Wu, Schreiber, Klementowicz, Biro, & Wright, 2001) and Tanner's standard photographs (Table 2.3) (Duke, Litt, & Gross, 1980; Neinstein, 1982; Wacharasindhu, Pri-Ngam, & Kongchonrak, 2002). A substantial agreement for BT stages, moderate agreement for GT stages and substantial to almost perfect agreement for PH Tanner stages in both genders between self-reported and raters' assessments obtained from this study are similar to a few previous studies (Duke, et al., 1980; Morris & Udry, 1980; Neinstein, 1982; Norris & Richter, 2005; S. J. Taylor, et al., 2001; Wacharasindhu, et al., 2002). In general, the agreement for GT stages was found to be lower than BT and PH Tanner stages. This may be due to the fact that boys may have difficulty in recalling the sizes of their testes and scrotum without visual depiction before answering the questionnaire. Providing a full-length mirror for the adolescents to examine their own sexual maturation status before answering the questionnaire has been shown to improve the agreements between children's self-assessment and raters' physical examination (Norris & Richter, 2005). Overall, the agreements between the children/adolescents and raters are substantial and significant for girls and moderately high for boys. Most agreements differed by one Tanner stage only.

The pattern of responses in this study showed that boys tended to rate themselves as less mature by underestimating their genitalia development which is consistent with the study done in Taipei (Wu, et al., 1993). The results may reflect cultural reticency of the Hong Kong Chinese male adolescents. However, girls tended to rate themselves as more mature by overestimating their breast Tanner stages. It may be postulated that this could be due to the influence of the mass media in emphasizing the importance of physical appearance of women.

Some studies have questioned the accuracy of the Tanner pubertal self-reported questionnaire (Desmangles, et al., 2006; Hergenroeder, et al., 1999; Schlossberger, Turner, & Irwin, 1992; Wu, et al., 1993). Disconcordance between self-reported and expert's assessment may be attributable to the small sample size (37 girls and 46 boys) of one study (Schlossberger, et al., 1992). A study done in Taiwan using grade 9 students to validate the Tanner pubertal self-reported questionnaire (Wu, et al., 1993) reported that the questionnaire was not a reliable tool to assess their participants. The authors concluded that their results might be explained by cultural reticency and little emphasis on sexual health education in the school curriculum.

Self-reported Pubertal Development Scale

We evaluated the performance of the Chinese version self-reported PDS against raters' physical assessment for the Hong Kong Chinese children/adolescents. The correlations between raters' assessment and children/adolescents's self-reported PDS were found to be from moderate to substantial. The agreements between raters' TDCS and children/adolescents's puberty category scores were moderately high. The accuracy rate of the complete agreement was higher for girls than boys. Most disagreements differed by one category which was similar to a previous study done in the United States (Schmitz, et al., 2004).

A study (Norris & Richter, 2008) reported that the self-reported PDS was a less reliable pubertal assessment tool in African adolescents in multiethnic community-based research. The authors noted that they were not sure of the literacy of their participants and had therefore asked participants to verbally respond to the PDS questionnaire instead of self-completion. This data collection method, with the implication that the participants had low levels of educational attainment, could also reflect that these students might have had limited understanding of their own pubertal development which could have influenced their selections and explain the negative findings of this study.

Weighted versus Unweighted Kappa

A stringent requirement for exact matching between children/adolescents' self-reported and raters' assessments may explain a low degree of agreement in other studies examining the performance of self assessment Tanner pubertal staging questionnaire (Desmangles, et al., 2006; Hergenroeder, et al., 1999) and PDS (Wu, et al., 1993). These studies used the unweighted kappa statistic for inter-observer reliability measures. However, using the unweighted kappa statistic for this type of study may not be optimal to reflect the actual clinical situation because the statistical results only distinguish between raters' agreement and disagreement without giving credit for near agreement. Since self-reported and rater's physical examination of sexual maturation status are both somewhat subjective and there is no exact cut-off of the Tanner pubertal stages, in particular Tanner stages 3 and 4, the concordance between raters should be allowed for differential weighting of different levels of disagreement. If validity is judged only on an exact match between self-reported and the rater's assessment, a low to moderate inter-rater reliability is to be expected. Our study adopted the Weighted Kappa statistic to analyze the data, which is a more appropriate method as it is an agreement statistic for ordered categories and allows differential weighting of different levels of disagreement (Cohen, 1968). Weighted Kappa gives high weights to responses that differ by one category, low weights to responses that differ by two and three categories and no weight is given to responses by four or more categories (Fleiss, Levin, & Paik, 2003).

The performance of the two self-reported pubertal questionnaires

It might be anticipated that agreements between the two self-reported pubertal assessment questionnaires (PDS and Tanner) of children/adolescents might be substantially high since children reported their own pubertal stage, albeit with two different instruments. However, most agreements and correlations between the children's two assessments were only from moderate to moderately high. This result may be attributed to the less well defined 4-point scale of the PDS, e.g. children may not know whether their sexual characteristics development "seems completed" or not, especially for children who are undergoing mid or late pubertal development. Definition can be given to each of the point scale so that children could be able to select the most appropriate point scale to indicate their pubertal stage.

In addition, sexual characteristic items for boys in the PDS are less specific than the Tanner pubertal assessment tool. Further study may be needed to consider items which are specific to the development of male sexual maturation status, e.g. male genitalia growth or/and spermarche and spermarcheal age, in the PDS. The occurrence of spermarche could be considered as a sexual maturation marker because spermarche was significantly associated with maturation of secondary sex characteristics (Hirsch, Lunenfeld, Modan, Ovadia, & Shemesh, 1985). Post-spermarcheal boys had also been found to have an increase in body size, shape, and physiological function during early and middle puberty (Ji, 2001). Over one-third of girls that achieved menarche were rated to be at stage III to IV and their age ranged from 10 to 13 years. This finding was similar to a previous United States study (Desmangles, et al., 2006). However, this important marker of sexual maturation is not included in the Tanner pubertal questionnaire. Menarchal status should be included as an indicator of girls' sexual maturation status. This information would be important for monitoring secular trends in female pubertal development.

The PDS items on growth in height and skin changes especially pimples were excluded from the sexual maturation status analysis in this study since these two items provide limited information for the estimated sexual maturation status of children. The growth spurt in height may vary in different children because it may be influenced by genetic and other factors such as nutrition and illness. Skin changes, especially pimples are not limited to adolescents, and may also be noted in adults. Data from these two items may be more appropriately monitored in longitudinal studies to compare child growth and development (Petersen, et al., 1988).

A downward trend in the mean age of menarche, as compared with previous Hong Kong studies with mean ages from 12.85 years in 1963 (Lee, Chang, & Chan, 1963), 12.2 years in 2002 (Lam, et al., 2002) to 11.5 years in the present study, was noted.

Although recall bias could be a factor when reporting age at menarche, this important event is likely to be recalled correctly and should not be a factor in explaining the secular trend. The earlier age of menarche may be explained by increased consumption of estrogen-containing foods (Saenz de Rodriguez, Bongiovanni, & Conde de Borrego, 1985) and warrants further research to better understand this potentially important phenomenon as earlier age of menarche has also been found to adversely affect changes in cardiometabolic risk factors (Remsberg et al., 2005).

Limitations

As only three schools (1 primary and 2 secondary) took part in the study, these results may not be representative of the Hong Kong population. The results of this study reflect the children's ability to recall their pubertal development since they did not have the opportunity to look at themselves before completing the questionnaire. Higher agreements might be anticipated if children are allowed to inspect themselves before filling out the questionnaires. However requirement for such self-inspection might be unsuitable when these tools are used in epidemiological studies. The PDS questionnaire was completed after the Tanner self-reported questionnaire. It is possible that reversing this order could influence the children's interpretation and the study results.

This study did not evaluate whether obesity might result in an over-estimation of breast stage in girls (either by self-reported or by rater assessment). The rater did not use palpation to differentiate fat tissue from breast tissue. Although this is a limitation of the study, we do not think it will have significantly influenced on our results since only 14% of the girls were classified as being overweight or obese. Further study would be required to determine whether obesity is a significant factor in pubertal self-assessment.

CONCLUSION

This study confirms that a Tanner pubertal self-reported questionnaire with line drawings and explanatory Chinese text and PDS are useful tools for estimating pubertal stage in Hong Kong children/adolescents. These two self-reported pubertal assessment tools may provide an alternative for population/ epidemiological studies for broad estimation of pubertal stage of children/adolescents when cost, privacy and other concerns preclude the use of other sexual maturation status assessment tools.

CHAPTER 3

METHODS, PROCEDURES, STATISTICAL ANALYSES

Preface

This chapter describes the methods of a Sleep study funded by Hong Kong's Research Grants Council (CUHK4465/06M). The study titled "Sleep duration, neurohormonal dysregulation and obesity in Hong Kong children and adolescents", was conducted from February 2007 to April 2008 using a cluster sampling method. A total of 2119 children aged 6-20 years were recruited and 2088 of these were eligible for inclusion in the analyses undertaken for this thesis. The primary aim of the Sleep study was to explore the associations between sleep duration, neurohormonal dysregulation and obesity in Hong Kong children and adolescents aged 6-18 years. The results of this study have been reported elsewhere (Kong et al., 2011; Kong et al., 2010; Kong et al. in press). Secondary aims of the study included the potential use of self-reported anthropometric measures to classify overweight/obesity and to predict cardiometabolic risk as explored in this thesis. The analyses reported in Chapter 4 to 6 utilize part of the database of the Sleep study but actual sample size varied depending on the purpose of the analyses as described in detail in the respective Chapters.

METHODS

Sample size

A total of 2119 participants aged 6-20 years, 804 primary school students and 1315 secondary school students, were recruited. 2102 participants who aged 6 to 20 years self-reported that they had no medical/psychiatric illnesses or long term medications. After excluding participants aged over 18 years old (Figure 3.1), there were 2088 (99.3%) participants aged 6 to 18 years eligible for inclusion in the analyses. Participants who had both corresponding measured and self-reported anthropometric values and self-reported pubertal staging, were included into the study where appropriate. Participants without corresponding measured and self-reported anthropometric values and self-reported pubertal stage were excluded from the respective analyses described in Chapters 4 to 6.

Sampling method

This was a cross-sectional study conducted from February 2007 to April 2008. The cluster sampling method of the Sleep study was based on that used for the Hong Kong Growth Study undertaken in 2005/06 (So, et al., 2008). A two-stage cluster sampling method was employed. In the first stage of the sampling, a complete list of all primary and secondary schools of all 18 districts in Hong Kong was obtained from the Education Bureau of Hong Kong to compile a sampling frame of all schools in Hong Kong. International and English Schools Foundation schools, which partly cater for expatriate non-Chinese children, were excluded. Selection of a school was based on computer-generated random numbers according to numbers of schools per district, and if the selected school declined to participate, the next randomly selected school was invited to participate. Although one primary school and one secondary school were randomly selected from each of the 18 Districts in Hong Kong for the 2005/06 Hong Kong Growth Survey (So, et al., 2008), only 5 primary schools and 6 secondary schools were randomly selected for the Sleep study. Children of Chinese ethnicity and without self-reported medical illnesses were recruited. In the second stage, two classes in each grade were selected in collaboration with the school principal based on timetables and operational needs. All students of the selected classes were invited to join the study.

Ethics Committee approval

The Sleep study was approved by the Joint Chinese University of Hong Kong - New Territories East Cluster Clinical Research Ethics Committee. Children were recruited after approval from school principals. Study information sheet and informed consent (Appendix 3.1) were sent to parents through a letter distributed by the school. Parents were told that children who participated in this study, would be given a record of their body measurements. If the child was found to have abnormal findings, he/she would be referred to the hospital for further assessment (Appendix 3.3). The parents and children were told that participation in the study was voluntary, that they could withdraw from the study at anytime without penalty and that all their information would be kept confidential.

PROCEDURES

After obtaining written consent from their parents or guardians together with the children's written or/and verbal consent, the children were given a self-administrated questionnaire to bring home for completion either by themselves or by their parents/guardians. The questionnaire included demographic data, self-reported variables such as BW, BH, WC, pubertal staging and medical illness and taking long term medications. The children/parents were not given any instructions for reporting their WC, BW and BH. Secondary school students were asked to complete the questionnaire by themselves and primary school students were asked to seek help from their parents/guardians for answering the questionnaire. Children were instructed to return the questionnaire and not to eat and drink anything for at least 8 hours for fasting blood samples on the day of the survey.

Data collection

On the day of data collection, the survey was conducted during the first two sessions in the morning to minimize interruption of normal school activities. The anthropometric measurements of children were taken by trained research staff. BW was measured with children standing without shoes, lightly clothed and recorded to the nearest 0.1 kg on a calibrated weight scale (weight scale model: Tanita physician digital scale, model number TBF-410, Tanita Corp., Tokyo, Japan). A correction of 0.5 kg was made for clothing for all children. Standing height was measured to the nearest 0.1 cm using a portable rigid stadiometer. When measuring the BH, the children were asked to look straight ahead, stand straight with heels together in bare or stockinged feet, put arms by their sides, touch the measuring rod of the stadiometer with their upper back, buttocks and heels and then stretch to a fully erect position with normal breathing. WC was measured twice to the nearest 0.1 cm at midway between the lowest rib and the superior border of the iliac crest at the mid-axillary line on bare skin without clothing during exhalation, while standing straight-up using a non-stretchable flexible measuring tape. The second measurement was taken immediately after the first measurement. The two measurements were then averaged. BP was measured twice from right arm after 5 minutes of rest in a seated relaxed position by a validated electronic blood pressure monitor (Omron, model number: T5, Omron Healthcare Inc., Tokyo, Japan). Children were asked to rest for

1 minute before the 2nd BP measurement, and the measurement was repeated (a third time) if the child's BP was greater than 120/80 mmHg. The retained values were the average of the two readings. The interval of data collection between self-reported and measured anthropometric values ranged from one to two weeks.

Laboratory analyses

After an overnight fast of at least 8 hours, blood samples were collected for measurement of fasting plasma glucose and lipid profile including total cholesterol, triglyceride, low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C) levels. All blood samples were kept in ice at 0°C and returned to the laboratory within 4 hours after collection either for assay or storage. Blood samples including fasting plasma glucose and lipid profile were assayed within 6 hours after collection and additional aliquots of serum for other assays were stored at -70°C. Glucose (hexokinase method), total cholesterol (enzymatic method), triglyceride (enzymatic method without glycerol blanking) and HDL-C (direct method using PEG-modified enzymes and dextran sulfate) were measured on a Roche Modular Analytics system (Roche Diagnostics GmbH, Mannheim, Germany) using standard reagent kits supplied by the manufacturer of the analyzer. The precision performance of these assays was within the manufacturer's specifications.

Definitions of cardiometabolic risk factors (CMRFs)

Children who have three or more out of five CMRFs are considered as having a clustering of CMRFs (Ng, et al., 2007; Sung, et al., 2007). The five CMRFs used in this study were as follows:

i) fasting triglycerides ≥ 90th percentile (age and sex specific) (Cruz, et al., 2004). Triglycerides values were logarithmically transformed to correct for skewness before subjected to analysis;

ii) fasting blood glucose ≥ 5.6 mmol/L (Zimmet, et al., 2007);

iii) fasting HDL-C ≤ 10th percentile (age and sex specific) (Cruz, et al., 2004);

iv) WC ≥ 90th percentile (age and sex specific) (Cruz, et al., 2004); and

v) either systolic blood pressure or diastolic blood pressure ≥ 90th percentile (age, sex and height specific) (Cruz, et al., 2004).

STATISTIC ANALYSES

Data were presented by appropriate descriptive statistics. Continuous and categorical data were respectively presented as mean (standard deviation) and frequency (%) for illustrating the sample characteristics. BMI was calculated as BW in kilogram (kg) divided by BH in meters squared (kg/m^2). BMI was calculated for each participant based on both self-reported and measured BW and BH values. Since there were some obvious extremes in self-reported values, a cutoff was adopted for defining outliers (Freedman, Pisani, & Purves, 1998). Those children with differences in self-reported and measured BW, BH and WC values greater than three standard deviations were considered as outliers and were excluded from the analysis. Overweight and obesity were defined as a BMI greater than the Hong Kong local age and gender specific 85^{th} and 95^{th} percentiles respectively (Ogden, et al., 2002; So, et al., 2008). Consistency between self-reported and measured values was assessed by the intra-class correlation coefficient (ICC). The term self-reported refers to the BW, BH and WC values reported by the children themselves, their parents or guardians from any source. Agreements of weight status based on MBMI, SRDBMI, SRWC and MWC was assessed using Cohen's kappa statistic.

Adopting the kappa benchmark (Landis & Koch, 1977), the strengths of agreement were as follows: ≤0.20=poor; 0.21-0.40=fair; 0.41-0.60=moderate; 0.61-0.80=substantial; >0.8=almost perfect. The mean differences between measured and self-reported anthropometric values by gender, weight status and school types were assessed using t-test or one-way ANOVA with Bonferroni correction for post hoc multiple comparisons. Chi square test was used to examine the association between pubertal stages and CMRFs. All the statistical analyses were performed using SPSS 17.0 (SPSS Inc., Chicago, IL). All statistical tests used were two-sided and a p-value <0.05 was considered statistically significant.

Diagnostic ability of SRDBMI, and SRWC to classify children with overweight/obesity status

Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) with [95% confidence intervals (CI)] were used to assess the diagnostic ability of self-reported anthropometric values to identify overweight and obesity, using measured anthropometric values as the reference method. Sensitivity (true-positive rate) is the probability of correctly detecting true overweight/obese status. Specificity (true-negative rate) is the probability of correctly detecting true normal weight status. PPV and NPV with 95% CI were used to denote the test results correctly identifying overweight/obese status among children according to SRDBMI data. The PPV was the proportion (%) of children who correctly identified themselves as overweight/obese, whereas the NPV was the proportion of children who correctly identified themselves as not overweight/obese.

Diagnostic ability of SRDBMI, and SRWC to classify children with a clustering of CMRFs

Area under receiver operator characteristic (AUC-ROC) curves analyses were employed to examine the diagnostic ability of SRWC for classifying overweight/obese status and CMRFs clustering in children. The areas under the ROC curve is a measure of the diagnostic ability of a test (self-reported or measured WC in our study) to classify those with and without a specified outcome (CMRFs clustering or overweight/obesity) satisfactorily. A value of 1 is considered as a prefect test, whereas a value of 0.5 or smaller indicates a result that is no better than a random guess or flipping a coin. Guidelines (Hosmer & Lemeshow, 2000) for interpreting AUC-ROC values are as follows: acceptable: $0.7 \leq AUC < 0.8$, excellent: $0.8 \leq AUC < 0.9$ and outstanding: $AUC \geq 0.9$. The AUC-ROC of SRDBMI and SRWC for classifying children with CMRFs clustering were compared to the measured values using the method suggested by DeLong (DeLong, DeLong, & Clarke-Pearson, 1988) and done using the PROC LOGISTIC (SAS Institute, Cary, NC, release 9.2).

The effect of pubertal stage on the prediction of CMRFs by BMI and WC

Given the small number of children that were identified with a clustering of CMRFs (n=54), the analysis would be underpowered to explore the moderator effect of pubertal stage on the prediction of CMRFs clustering by WC or BMI. Therefore another approach using a summary risk score to quantify the CMRFs was used to examine the potential moderator effect.

A summary risk score, based on The European Youth Heart Study (Andersen et al., 2006), was constructed to quantify CMRFs clustering for the population sample of school children in Hong Kong. The components of the score were selected on the basis of the International Diabetes Federation (Zimmet, et al., 2007) and modified National Health and Nutrition Survey (Ng, et al., 2007) definitions of metabolic syndrome. Specifically, the score consists of six components: WC, triglycerides, LDL-C, fasting blood glucose, HDL-C and BP (either systolic BP or diastolic BP). The risk score (α) was computed by summing up the following:

(1) z-score of sex specific age-adjusted WC
(2) z-score of sex specific age-adjusted triglyceride
(3) z-score of sex specific age-adjusted LDL-C
(4) z-score of sex specific age-adjusted fasting blood glucose
(5) minus z-score of sex specific age-adjusted HDL-C
(6) the greater one of z-score of sex specific age and height adjusted systolic BP and z-score of sex specific age and height adjusted diastolic BP.

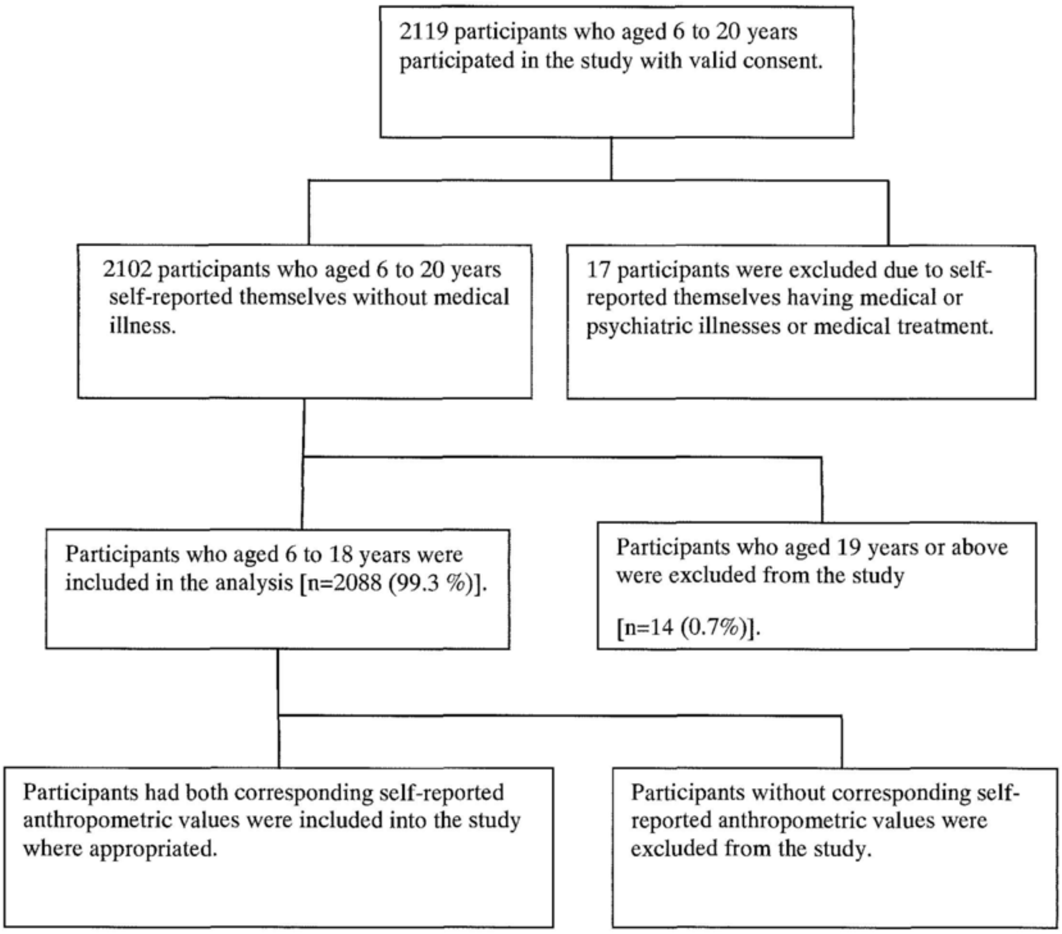
Each of the component variables of the risk score was regressed with age (and height as well for systolic BP and diastolic BP) for boys and girls separately. The standardized residuals were retained to represent the z-score of age-adjusted values for each component variables. In parallel, a CMRFs score (β) without the central obesity component (i.e. WC) was also calculated for the sake of comparison.

Hierarchical multiple regression analyses were used to examine the moderator effect of pubertal stage on the prediction of CMRFs by WC or BMI. All the statistical analyses were conducted separately for boys and girls. Z-score of unadjusted WC / BMI was first entered into regression model with the CMRFs score as the dependent variable. Then pubertal stage was recoded as two dummy variables (pubertal and post-pubertal with pre-pubertal as reference) and entered into the regression. Finally, the interaction terms of the pubertal stage and z-score of WC / BMI were entered into the regression model. The significance of the additional terms included as compared with the preceding model was assessed using F-test. The moderator effect of pubertal stage was indicated by the significance of the interaction terms added to the regression model.

The definition of prepubertal, pubertal and late/post pubertal stage

The five Tanner pubertal stages were combined into 3 pubertal stages, namely prepubertal stage, pubertal stage and late/post pubertal stage. The prepubertal stage is equivalent to the Tanner pubertal stage 1. The pubertal stage is the average of Tanner pubertal stage 2 and 3. The late/pubertal stage is the average of Tanner pubertal stage 4 and 5. The average scores were rounded to the highest pubertal stage so as to avoid underestimating the pubertal stage (Chan et al., 2010).

Fig 3.1 Flow chart showing the recruitment of participants who were included in and excluded from the study



CHAPTER 4

ASSESSMENT OF SELF-REPORTED BODY WEIGHT AND BODY HEIGHT

Preface

This chapter presents the agreement of body weight (BW) and body height (BH) between children/adolescents self-reported and assessor measured values and the diagnostic ability of self-reported body weight and height derived body mass index (SRDBMI) to classify children with overweight/obesity status and a clustering of cardiometabolic risk factors (CMRFs). Given that BMI is the most common overweight/obesity screening tool, an understanding of the agreement of the BW and BH between measured and self-reported values as well as the diagnostic ability for classifying children with overweight/obesity status and CMRFs clustering could provide alternative assessment method for screening overweight/obesity in children in community settings and epidemiological research

INTRODUCTION

Anthropometric measures such as BMI (Freedman & Sherry, 2009) is commonly used for assessing overweight/obesity. BMI is calculated as BW in kilogram divided by BH in metre square. Children with high BMI for age are more likely to have a clustering of CMRFs (Freedman, et al., 2007; Thompson et al., 2007). Encouraging parents and children to monitor overweight and obesity may lead to greater awareness, earlier detection and improved treatment compliance of overweight/obesity. SRDBMI has been recommended for monitoring prevalence of obesity, particularly for large-scale studies or screening for overweight/obesity in community settings because of simplicity and low cost (Brener, McManus, Galuska, Lowry, & Wechsler, 2003; Fonseca et al., 2010; Goodman & Strauss, 2003; John H. Himes, Hannan, Wall, & Neumark-Sztainer, 2005). Although some studies suggest that SRBW and SRBH can reliably estimate measured BW (MBW) and BH (MBH) (Brener, et al., 2003; Himes, et al., 2005), others have questioned the usefulness of these self-reported values (Elgar, Roberts, Tudor-Smith, & Moore, 2005; Elgar & Stewart, 2008; Fonseca, et al., 2010; Himes & Faricy, 2001; Larsen, Ouwens, Engels, Eisinga, & Van Strien, 2008; Lee, Valeria, Kochman, & Lenders, 2006;

Tokmakidis, Christodoulos, & Mantzouranis, 2007; Wang, Patterson, & Hills, 2002). Studies using SRDBMI to classify overweight/obesity in children have also yielded inconsistent findings (Brener, et al., 2003; Tokmakidis, et al., 2007). As SRDBMI is simple, low cost and non-invasive assessment tool, this may be a useful clinical screening tool to identify and monitor the prevalence of overweight/obesity and the related risk factors in community settings or epidemiological research.

Aims of the study

To the best of our knowledge, no previous study has assessed the agreement of SRBW and SRBH with measured values in Hong Kong Chinese children aged 6-18 years. We set out to do this and to evaluate whether SRDBMI could appropriately classify our children with overweight/obese status and CMRFs clustering.

Objectives of the study

1) Assess the agreement of BW and BH between self-reported and measured values;
2) Examine the diagnostic ability of SRDBMI for classifying overweight and obesity status;
3) Examine the diagnostic ability of SRDBMI in classifying children with CMRFs clustering

METHODS, PROCEDURES AND STATISTICAL ANALYSES

Methods, procedures and statistical analyses on the agreement of SRBW and SRBH with measured values have been described in Chapter 3 methods, procedures and statistical analyses.

RESULTS

Assessment of self-reported body weight and body height

A total of 1614 children (671 boys and 943 girls) were included in the analysis (Fig 4.1) of SRBW and SRBH. There were 13.4% children aged 6-8 years, 21.8% aged 9-11 years, 27.1% aged 12-14 years, 23.2% aged 15-16 years and 14.6% aged 17-18 years. Table 4.1 shows the background characteristics of these children. The ICC results demonstrated good consistency between measured and self-reported values for BW, BH and the derived BMI (Table 4.2). The Cohen's kappa (95% CI) statistic revealed substantial agreement for weight status defined by MBMI and SRDBMI (Table 4.2).

Fig 4.1 Flow chart showing the recruitment of participants who were included in and excluded from the study

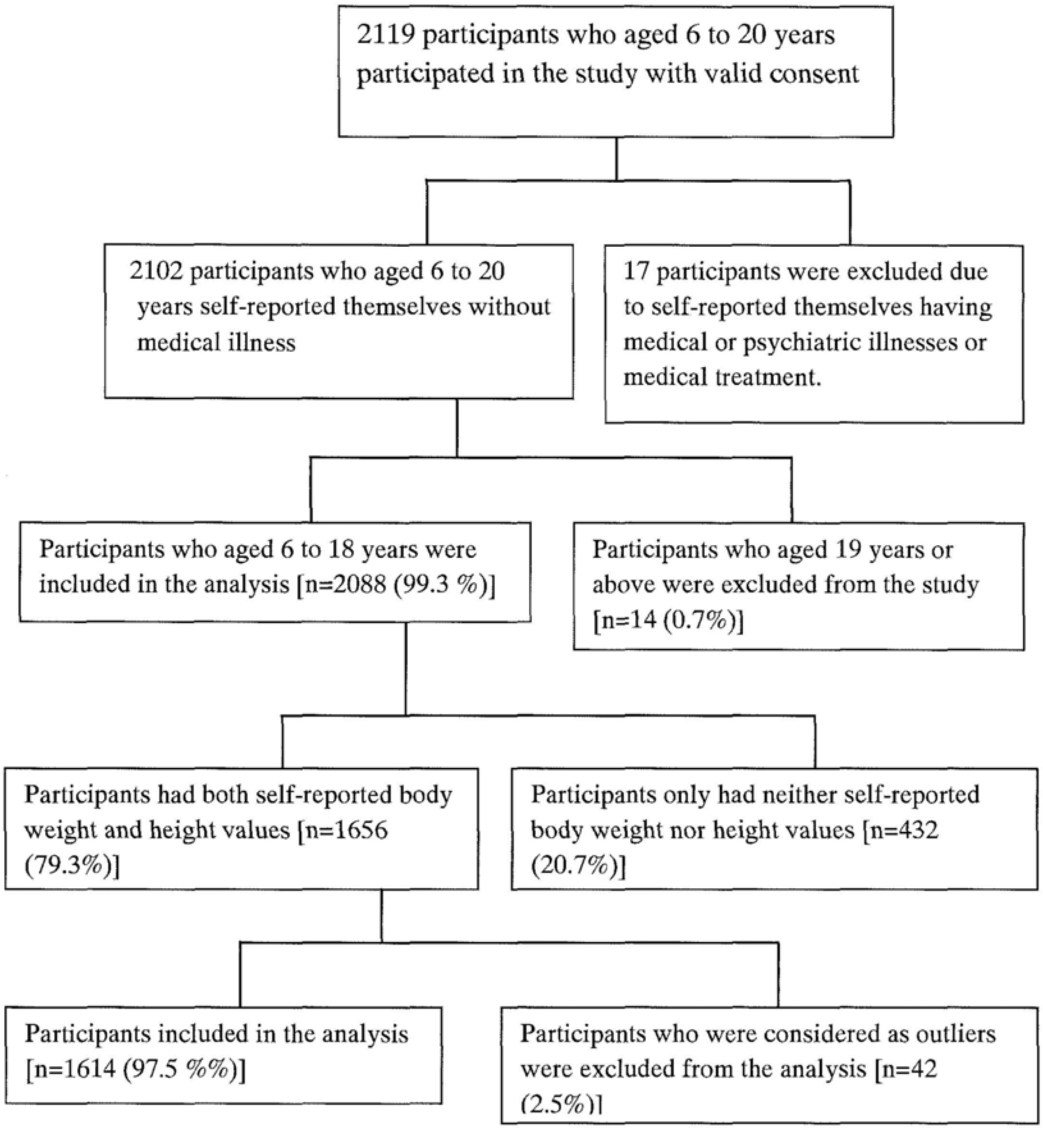


Table 4.1 Background characteristics of participants aged 6-18 years who were included and excluded from the study

	Participants were eligible for the analysis (n=2088)	Participants were included in the analysis (n=1614)	Participants were considered as outliers and excluded from the analysis (n=42)	Participants who did not have both self-reported BW and BH values were excluded from the analysis (n=432)
Sex				
Male #	881 (42.2%)	671 (41.6%)	25 (59.5%)	185 (42.8%)
Female #	1207 (57.8%)	943 (58.4%)	17 (40.5%)	247 (57.2%)
Age (yrs) *	13.3 (3.3)	13.3 (3.3)	12.1 (3.2)	13.3 (3.4)
Body weight (kg) *	44.8 (13.4)	45.1 (13.3)	42.7 (13.7)	43.7 (13.9)
Body height (cm) *	152.2 (15.1)	152.4 (14.8)	151.4 (16.2)	151.1 (15.9)

frequency (percentage), * mean (sd)

Table 4.2 Measured and self-reported body weight, height and weight status of 1614 children aged 6-18 years

	Boys (n=671)			Girls (n=943)		
	Measured	Self-reported	ICC / Cohen's Kappa (95% CI)	Measured	Self-reported	ICC / Cohen's Kappa (95% CI)
Body weight (kg) *	46.9 (15.2)	46.4 (15.0)	0.99 (0.98 – 0.99) †	43.8 (11.6)	43.2 (11.4)	0.98 (0.98 – 0.98) †
Body height (cm) *	154.2 (17.3)	153.8 (17.8)	0.99 (0.99 – 0.99) †	151.2 (12.7)	151.1 (13.5)	0.99 (0.98 – 0.99) †
BMI (kg/m^2) *	19.2 (3.5)	19.1 (3.5)	0.94 (0.93 – 0.95) †	18.8 (3.1)	18.6 (3.0)	0.93 (0.93 – 0.94) †
Weight status #			0.76 (0.71 – 0.81) Ψ			0.76 (0.71 – 0.82) Ψ
Normal	499(74.4%)	504 (75.1%)		783 (83.0%)	795 (84.3%)	
Overweight	106 (15.8%)	100 (14.9%)		106 (11.2%)	94 (10.0%)	
Obese	66 (9.8%)	67 (10.0%)		54 (5.7%)	54 (5.7%)	

frequency (percentage), * mean (sd) † ICC: intraclass correlation coefficient ; Ψ Cohen's Kappa

Table 4.3 Frequency of difference between measured and self-reported body weight and height (%)

Difference between measured and self-reported values	All boys (n=671)				All girls (n=943)			
	± 0.99 unit	±1-1.99 unit	±2-2.99 unit	≥ 3 unit	± 0.99 unit	±1-1.99 unit	±2-2.99 unit	≥ 3 unit
Body weight (kg)	283 (42.2%)	167 (24.9%)	86 (12.8%)	135 (20.1%)	444 (47.1%)	239 (25.3%)	128 (13.6%)	132 (14.0%)
Body height (cm)	185 (27.6%)	207 (30.8%)	136 (20.3%)	143 (21.3%)	284 (30.1%)	305 (32.3%)	188 (19.9%)	166 (17.6%)

Difference between measured and self-reported values	Overweight/obese boys (n=172)				Overweight/obese girls (n=160)			
	± 0.99 unit	±1-1.99 unit	±2-2.99 unit	≥ 3 unit	± 0.99 unit	±1-1.99 unit	±2-2.99 unit	≥ 3 unit
Body weight (kg)	62 (36.0%)	39 (22.7%)	27 (15.7%)	44 (25.6%)	64 (40.0%)	36 (22.5%)	29 (18.1%)	31 (19.4%)
Body height (cm)	42 (24.4%)	49 (28.5%)	38 (22.1%)	43 (25.0%)	40 (25.0%)	52 (32.5%)	42 (26.3%)	26 (16.3%)

Table 4.4 Difference between measured and self-reported weight and height by gender, weight status and school types

	Measured – self-reported mean (sd)	
	Body weight (kg)	Body height (cm)
Gender		
Male	0.55 (2.62)	0.45 (2.34)
Female	0.60 (2.21)	0.13 (2.11)
p-value†	0.657	0.005
Weight status		
Normal	0.36 (2.18)	0.25 (2.20)
Overweight / obese	1.41 (2.92)	0.32 (2.29)
p-value†	<0.001	0.636
School types		
Primary	0.58 (2.34)	1.21 (2.49)
Secondary	0.58 (2.42)	-0.32 (1.80)
p-value†	0.989	<0.001

† Student's t-test

The proportions of all children and obese children reporting their BW and BH absolute values within 1 unit (1kg, 1cm) or greater, are detailed in Table 4.3. About 80% of all boys and 85% of all girls reported values of less than 3 units (3kg, 3cm). Differences between measured and self-reported BW and BH varied by weight status, gender and school types (primary or secondary school) (Table 4.4). Overweight/obese children significantly under-reported their BW as compared to the normal weight children. Boys underestimated their BH values significantly less than did girls. Secondary school children reported their BH values to be significantly higher than did primary school children.

The diagnostic ability of SRDBMI in classifying children with overweight/obesity status

172 boys and 160 girls were categorized as overweight/obese by measured values and 167 boys and 148 girls by self-reported values (Table 4.5). The gender-specific test values for the classification of overweight/obese based on the self-reported data exhibited high sensitivity and specificity in classifying children as being overweight/obese. Based on calculation of SRDBMI from SRBW and SRBH values, a high proportion of children would be correctly classified as overweight/obese (PPV 0.87 for boys and 0.90 for girls) and a very high proportion would be classified as being of normal weight (NPV 0.95 for boys and 0.97 for girls) (Table 4.5).

The diagnostic ability of SRDBMI in classifying children with CMRFs clustering

The gender-specific AUC-ROCs of both MBMI and SRDBMI for classifying a clustering of CMRFs and overweight/obesity status in children are presented in Table 4.6 and Figure 4.2. The AUC-ROCs of self-reported values were 0.85 for boys and 0.87 for girls which were very close to measured values of 0.85 for boys and 0.89 for girls. The gender-specific values which were based on the SRDBMI values, exhibited substantial sensitivity (80% for boys and 83% for girls) and specificity (78% for boys and 79% for girls) for classifying children with CMRFs clustering.

Table 4.5 Sensitivity, specificity, PPV and NPV of children's SRDBMI using measured values as the reference method

	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Boys (n=172)				
Overweight/obese (n=172)	0.84 (0.78 - 0.89)	0.96 (0.93 - 0.97)	0.87 (0.81 - 0.91)	0.95 (0.92 - 0.96)
Obese (n=66)	0.85 (0.74 - 0.92)	0.98 (0.97 - 0.99)	0.84 (0.73 - 0. 91)	0.98 (0.97 - 0.99)
Girls (n=160)				
Overweight/obese (n=160)	0.83 (0.77 - 0.88)	0.98 (0.97 - 0.99)	0.90 (0.84 - 0.94)	0.97 (0.95 - 0.98)
Obese (n=54)	0.78 (0.65 - 0.87)	0.99 (0.98 - 0.99)	0.78 (0.65 - 0.87)	0.99 (0.98 - 0.99)

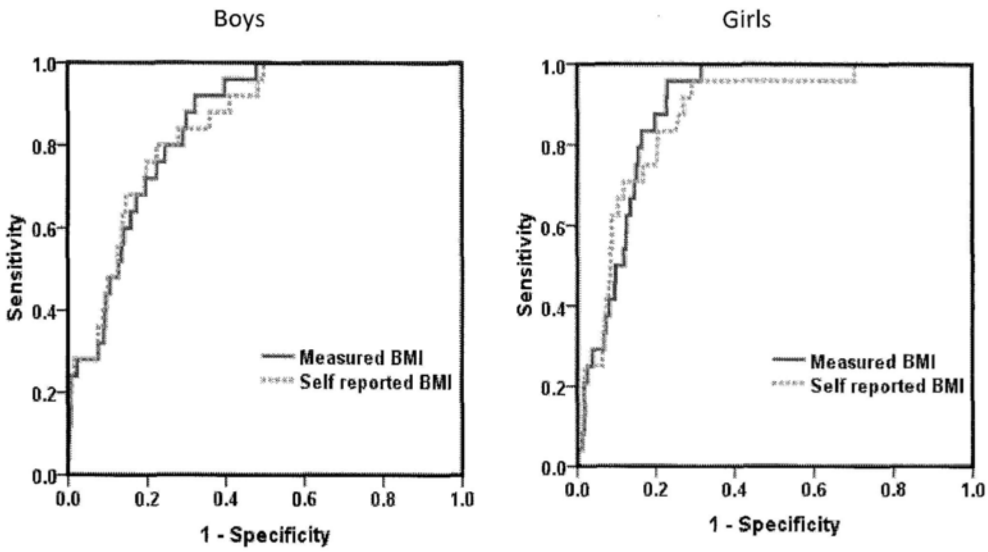
PPV: Positive predicted value NPV: Negative predicted value

Table 4.6 Comparison on diagnostic ability between measured and self-reported BMI for classifying a clustering of cardiometabolic risk factors (CMRFs)*

	AUC-ROC (95% CI) $^{\Psi}$	Optimal threshold (percentile)	Sensitivity (95% CI)	Specificity (95% CI)
Boys				
Measured BMI	0.85 (0.80 - 0.91)	73.8	0.80 (0.59 - 0.93)	0.75 (0.72 - 0.79)
Self-reported BMI	0.85 (0.79 - 0.91)	75.9	0.80 (0.59 - 0.93)	0.78 (0.74 - 0.81)
Girls				
Measured BMI	0.89 (0.85 - 0.93)	82.1	0.83 (0.63 - 0.95)	0.84 (0.81- 0.86)
Self-reported BMI	0.87 (0.81- 0.93)	78.0	0.83 (0.63 - 0.95)	0.79 (0.77- 0.82)

* clustering of cardiometabolic risk factors (CMRFs) was definied as 3 or more of the followings:
(1) Waist circumference $\geq 90^{th}$ percentile (age and sex specific);
(2) Triglyceride $\geq 90^{th}$ percentile (age and sex specific);
(3) HDL-C $\leq 10^{th}$ percentile (age and sex specific);
(4) fasting blood glucose $\geq$ 5.6 mmol/L
(5) either systolic BP or diastolic BP $\geq 90^{th}$ percentile (age, sex and height specific);
$^{\Psi}$ Area under the receiver operating characteristic curve;

Figure 4.2 Receiver operating characteristic curves for classifying a clustering of cardiometabolic risk factors by measured BMI and self-reported derived BMI in boys and girls



DISCUSSION

This study evaluated the agreement of BW and BH between self-reported and measured values and the ability of SRDBMI to correctly classify children with overweight and obese status and CMRFs clustering. The SRBW and SRBH demonstrated good consistency with the measured values. The agreements of weight status, BW and BH between measured and self-reported values ranged from substantial to almost perfect (Table 4.2). The results of sensitivity and specificity analyses showed that the majority of boys and girls could be appropriately classified as overweight/obese when using self-reported values to calculate SRDBMI (Table 4.5). Using weight status defined by measured BMI as the reference value, less than one-fifth of children with overweight/obese status would be mis-classified as normal BMI. However, this group of students may have a high fat mass and this is particularly true for Asian populations. The children/adolescents who were mis-classified, could be at higher risk of overweight/obesity and could probably benefit from healthy lifestyle recommendations i.e.mis-classification is unlikely to have negative health impacts.

The self-reported values could satisfactorily classify overweight/obese status among children as reflected from high PPV and NPV results. Our findings are consistent with some previous studies that showed children's SRBW and SRBH could appropriately classify children's obesity status (Brener, et al., 2003; Himes, et al., 2005). We attempted to examine the diagnostic ability of SRDBMI to classify children with CMRFs clustering using AUC-ROCs compared to MWC. The results of the AUC-ROCs showed that SRDBMI could have value as a screening tool for classifying a clustering of CMRFs in our population.

About 42% of our boys and 47% of our girls reported their BW values within 1kg of the measured values. A difference in BW of less than 1kg can be was considered as almost perfect agreement, since BW will vary slightly from day to day depending on clothing worn and timing of measurement, e.g. before or after ingestion of food/drink or/and elimination. About 28% and 31% of our boys and 30% and 32% of our girls reported their BH values within 1cm and 1-2cm of the measured values respectively. It is likely that SRBH could differ from measured values for various reasons e.g. standing posture, whether shoes are worn. Therefore we considered discrepancies of BW and BH between self-reported and measured values of less than 1kg and 2cm respectively to be within the expected measurement variability.

The majority of children tended to report both their BW and BH lower than measured values. There may be several reasons for these findings. First, according to our personal discussions with school personnel, most schools in Hong Kong measure BW and BH of their students at least once during the academic year. Furthermore, every year the majority of Hong Kong students attend the Student Health Service of the Department of Health for health screening that includes BW and BH measurements. These measurements are recorded in both the students' handbook and the Student Health Service Record that are kept by students. Parents and/or students may have reported their BW and BH measurement values directly from these two sources. A time lapse between recording these measurements and abstracting these to the questionnaire could also explain the trend to underestimating self-reported values. Although some families would have used household scales and measurement tapes to obtain measures at the time of completing the questionnaire, we did not collect information about the source of the self-reported measures. We subtracted 0.5kg from the measured BW to adjust for the weight of a school uniform but a similar adjustment is unlikely to have been made for SRBW. This could imply that the tendency to under-report BW was even greater than that identified. However the tendency to underreport both SRBW and SRBH values likely balanced out and resulted in a smaller discrepancy in the calculated SRDBMI values.

A significant gender difference in reporting BH was noted. Girls reported their BH more accurately than did boys. Differences of BH between measured and self-reported values were also significantly higher for secondary school children when compared to primary school children. This age effect could in part reflect the proportionate difference of a unit measure in weight (1kg) and height (1cm) between the heavier and taller secondary students as compared to the lighter and shorter primary students. Overweight/obese children underreported their weight significantly more than did normal weight status children. These findings are consistent with other studies showing that overweight children tend to underreport their BW (Brener, et al., 2003; Elgar, et al., 2005; Elgar & Stewart, 2008; Fonseca, et al., 2010; Larsen, et al., 2008) and older children tend to over-report their BH (Brener, et al., 2003), possibly reflecting the social desirability of being tall and slim.

Limitations on the study of self-reported body weight and body height

Several limitations of this study are worth noting. Children who participated in the study were from selected classes and they would have been aware that their BW and BH were going to be measured. This may have prompted them to report their anthropometric values more accurately than would have occurred otherwise. Although some authors have examined the agreement between measured and SRBW and SRBH values using the Bland-Altman method (Elgar, et al., 2005; Fonseca, et al., 2010; Wang, et al., 2002), we considered this approach less appropriate to assess self-reported values based on self-perception or self-measurement without standardization of the BW and BH measurement methods. However, it would be interesting to compare the differences between self-reported results with and without specific instructions being given to children and parents for BW and BH measurements in further study. It is also worth noting that although BMI was used to identify overweight/obese children, this measure fails to distinguish fat, muscle and bone mass. Classifying overweight/obesity based on BMI can exaggerate the rate of overweight/obesity in muscular children or in those with a large body frame. Waist circumference may better assess abdominal obesity in children and identify those at cardiometabolic risk (Cheng, 2009; Sung, et al., 2008).

In the absence of generally accepted criteria to define outliers, we adopted an arbitrary, although commonly used, cutoff for this. Although it can be argued that exclusion of outliers is not appropriate for a study aiming to assess the agreement between self-assessed and measured values, other similar studies (Brener, et al., 2003; Larsen, et al., 2008) have also excluded outliers from the analysis. An *a priori* algorithm to remove outliers prior to analysis could be a solution, i.e. based on the age and sex of the child, obvious errors in measurement might be identifiable if inches instead of centimeters or pounds instead of kilograms might have been reported. Measures that would be biologically implausible could be included in such an algorithm. Further study would be required to see the feasibility of such *a priori* exclusions. There were relatively few outliers (2.5%) and re-running the analysis with the inclusion of these outliers produced similar results (data not shown), suggesting that exclusion of outliers did not impact on our overall conclusions.

We did not ask whether it was the parents or the child who had completed the questionnaire or how the measurements were obtained. This information could provide insight for further analysis. Finally, since most Hong Kong students have yearly BH and BW measurements at the Student Health Service, our results may not be replicable in other settings where such measures are not regularly undertaken.

CONCLUSION

Given that obesity in children is significantly associated with a clustering of CMRFs, monitoring rates of obesity is of great importance. Limitations of resources and the magnitude of the problem emphasize the desirability to have a low-cost screening tool for estimating weight status of children and to identify overweight/obesity. Our study showed that BW and BH demonstrate good consistency between measured and self-reported values and the SRDBMI provides estimates of overweight and obesity status and CMRFs clustering from a population perspective in Hong Kong Chinese children.

CHAPTER 5

ASSESSMENT OF SELF-REPORTED WAIST CIRCUMFERENCE

Preface

This chapter presents the agreement of WC between children/adolescents self-reported and assessors' measured values and the diagnostic ability of SRWC to classify children with a clustering of CMRFs and overweight and obesity status in Hong Kong Chinese children aged 6-18 years. WC measurement is a potentially simple and cheap method and a surrogate assessment tool for assessing central fatness. As it is highly associated with increased risk for cardiometabolic disorders, an understanding of the performance of SRWC against measured values and its diagnostic ability for classifying children with CMRFs clustering and overweight and obesity status could provide valuable information for monitoring overweight and obesity in children in community settings and for epidemiological research.

INTRODUCTION

Waist circumference (WC) is a highly sensitive, specific and reproducible surrogate measure of upper and abdominal fat in children and adolescents at different ages (Daniels, Khoury, & Morrison, 2000; Moreno et al., 2002; Taylor et al., 2000) and hence WC offers a more sensitive measure of overweight/obesity than BMI (McCarthy and Ashwell, 2006). Longitudinal data from the European Prospective Investigation into Cancer and Nutrition study showed that WC is a better indicator of mortality particularly among persons with low BMI (Pischon et al., 2008). A study has also found that WC is a better predictor for the presence of CMRFs than BMI in children (Savva et al., 2000). It is often used as a surrogate marker of abdominal fat mass for identifying children with central obesity. WC only requires a tape measure to obtain the measurement results while BMI needs a well-maintained weight scale, stadiometer, correct body height measurement technique as well as an accurate BMI calculation. Conversely there is no agreement on exactly where and how to measure WC (Table 1.3).

Although self-reported body weight (SRBW) and body height (SRBH) to derive BMI (SRDBMI) has been recommended for monitoring prevalence of obesity, particularly for large-scale studies or screening for overweight/obesity in community settings because of simplicity and low cost (Brener, et al., 2003; Fonseca, et al., 2010; Goodman & Strauss, 2003; Himes, Hannan, Wall, & Neumark-Sztainer, 2005), self-reported waist circumference (SRWC) measurement is potentially more straightforward than SRDBMI. SRWC may be one of the useful screening tools to identify and monitor the prevalence of overweight/obesity and the related risk factors in population/epidemiological research and community settings when cost, time and privacy preclude the use of other anthropometric measurements. To the best of our knowledge, no study has assessed SRWC against assessor measured WC (MWC) and evaluated its diagnostic ability to classify a clustering of CMRFs and overweight/obesity status in children.

Aims of the study

The aims of this study were: first, to assess the agreement of WC between self-reported and measured values and secondly, to assess the diagnostic ability of SRWC to classify a clustering of CMRFs and overweight/obese status in Hong Kong Chinese children aged 6-18 years.

Objectives of the study

1) Assess the agreement of WC between self-reported and measured values;
2) Examine the diagnostic ability of SRWC in classifying children with overweight and obesity status;
3) Examine the diagnostic ability of SRWC in classifying children with a clustering of CMRFs.

METHODS, PROCEDURES AND STATISTICAL ANALYSES

Methods, procedures and statistical analyses on the performance of SRWC have been described in Chapter 3 methods, procedures and statistical analyses.

RESULTS

After excluding participants aged over 18 years, outliers, students having medical/psychiatric illnesses, medical treatment/ long term medications and those who did not report their WC, a total of 1226 children including 515 boys and 711 girls were eligible to enter data analysis for the variables studied (Figure 5.1). The characteristics of the included and excluded children are shown in Table 5.1. Table 5.2 presents background characteristics, anthropometric measures and CMRFs profile of the children included in this study. The prevalence of overweight and obesity [BMI ≥ 85^{th} percentile (Ogden, et al., 2002)] was 25.6% for boys and 17.2% for girls. Of all the children, 3.8% (n=19) boys and 2.7% (n=19) girls were classified as having a clustering of CMRFs (≥3 risk factors).

Table 5.1 Characteristics of the participants that were included and excluded for the self-reported waist circumference study

	All participants who were aged 6 – 18 years included in the study (n=2088)	Participants were included in the analyses (n=1226)	Participants were considered as outliers and excluded from the analyses (n=21)	Participants without self-reported WC and were excluded from the analyses (n=841)
Sex #				
Male	881 (42.2%)	515 (42.0%)	4 (19.0%)	362 (43.0%)
Female	1207 (57.8%)	711 (58.0%)	17 (81.0%)	479 (57.0%)
Age (yrs) *	13.3 (3.3)	13.4 (3.2)	11.9 (3.0)	13.1 (3.4)
Waist circumference(cm) *	65.0 (9.0)	65.2 (8.9)	64.4 (10.6)	64.6 (9.1)

frequency (percentage), * mean (sd)

Table 5.2 Background and cardiometabolic risk factors characteristics of the children included in the self- reported waist circumference study (n=1226)

	All (n=1226)	Boys (n=515)	Girls (n=711)
Sex #			
Male	515 (42.0%)	–	–
Female	711 (58.0%)	–	–
Age (yrs)	13.4 (3.2)	13.2 (3.2)	13.7 (3.2)
Waist circumference(cm)	65.2 (8.9)	66.9 (9.9)	64.0 (7.9)
BMI (kg/m^2)	19.0 (3.3)	19.3 (3.5)	18.8 (3.1)
BMI z-scores	0.16 (1.03)	0.26 (1.03)	0.08 (1.02)
Weight status #			
Normal	972 (79.3%)	383 (74.4%)	589 (82.8%)
Overweight	162 (13.2%)	82 (15.9%)	80 (11.3%)
Obese	92 (7.5%)	50 (9.7%)	42 (5.9%)
Systolic blood pressure (mmHg)	110.5 (11.5)	114.4 (12.3)	107.7 (10.0)
Diastolic blood pressure (mmHg)	67.0 (8.4)	66.6 (8.5)	67.3 (8.3)
HDL cholesterol (mmol/L)	1.6 (0.3)	1.6 (0.3)	1.6 (0.4)
Fasting plasma glucose (mmol/L)	4.7 (0.4)	4.8 (0.4)	4.7 (0.3)
Triglyceride (mmol/L) †	0.7 (0.6 – 1.0)	0.7 (0.5 – 0.9)	0.8 (0.6 – 1.0)
Clustering of CMRFs #			
No	1171 (96.9%)	487 (96.2%)	684 (97.3%)
Yes	38 (3.1%)	19 (3.8%)	19 (2.7%)

Data marked with# are presented as frequency (percentage), † median (interquartile range), all others are presented as mean (standard deviation).
Overweight: BMI ≥ 85^{th} percentile
Obesity: BMI ≥ 95^{th} percentile

Fig 5.1 Flow chart showing the recruitment of participants for the self-reported waist circumference study

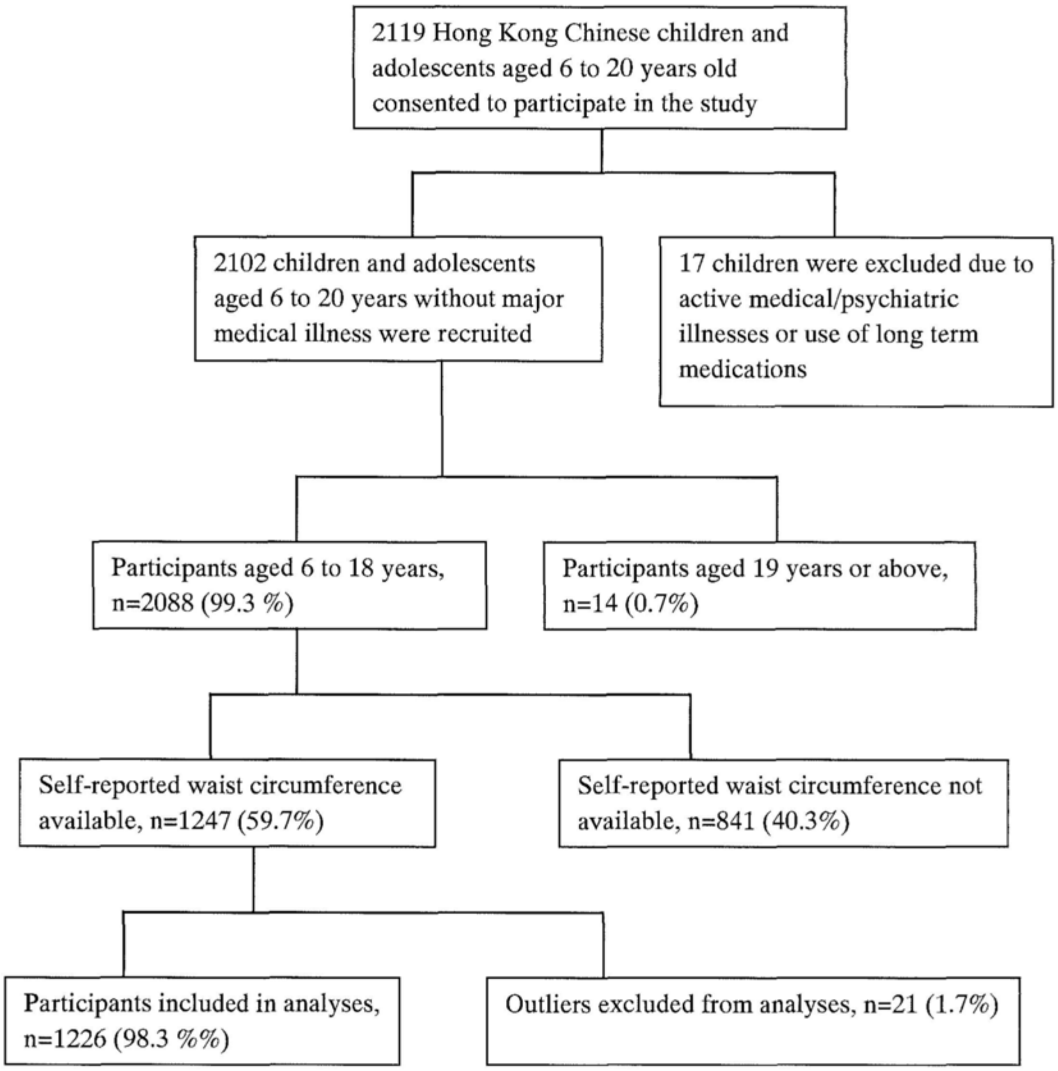


Table 5.3 shows the frequency of over-reporting and under-reporting WC between measured and self-reported values. Of all children, more than one third (33.2%) of boys and two-fifths (40.9%) of girls reported their WC absolute value less than 2 centimeters (cm) and more than half of boys (55.7%) and almost two-fifths (37.8%) of girls tended to over-report their WC when compared to MWC. Table 5.4 shows mean differences and intra-class correlation coefficients between MWC and SRWC of all children according to sex, age, weight status and school types. The mean of SRWC were higher than the mean of MWC for all children and for all subgroups analysis indicating that most children tended to over-report their WC. Student's t-test and one-way ANOVA showed that the mean differences of SRWC values were significantly higher than MWC values by gender, age groups, weight status and school types. Boys and primary school children reported significantly higher values for their WC than did girls' and secondary school children respectively. Post Hoc multiple comparisons with Bonferroni adjustment showed that the age group 9-10 years reported their WC values significantly higher than that of the age groups 15-16 years ($p=0.042$) and 17-18 years ($p=0.011$), normal weight children reported their WC value significantly higher than did the overweight group ($p=0.006$) and obese group ($p<0.001$). The agreement of SRWC with measured values yielded ICC values from substantial to almost perfect (from 0.77 to 0.87).

Table 5.3 Frequency of over-reported and under-reported waist circumference between the self-reported and measured waist circumference values

Waist circumference (cm)	±0 – 1.99cm	Under-reported	Over-reported
All (n=1226)	462 (37.7%)	208 (17.0%)	556 (45.4%)
Sex			
Boys (n=515)	171 (33.2%)	57 (11.1%)	287 (55.7%)
Girls (n=711)	291 (40.9%)	151 (21.2%)	269 (37.8%)
Age (yrs)			
6 – 8 (n=160)	59 (36.9%)	20 (12.5%)	81 (50.6%)
9 – 10 (n=134)	38 (28.4%)	17 (12.7%)	79 (59.0%)
11 – 12 (n=225)	85 (37.8%)	35 (15.6%)	105 (46.7%)
13 – 14 (n=232)	87 (37.5%)	43 (18.5%)	102 (44.0%)
15 – 16 (n=293)	117 (39.9%)	56 (19.1%)	120 (41.0%)
17 – 18 (n=182)	76 (41.8%)	37 (20.3%)	69 (37.9%)
Weight status			
Normal (n=972)	376 (38.7%)	143 (14.7%)	453 (46.6%)
Overweight (n=162)	60 (37.0%)	37 (22.8%)	65 (40.1%)
Obese (n=92)	26 (28.3%)	28 (30.4%)	38 (41.3%)
School types			
Primary (n=453)	158 (34.9%)	67 (14.8%)	228 (50.3%)
Secondary (n=773)	304 (39.3%)	141 (18.2%)	328 (42.4%)

Under-reported : self-reported – measured ≤ -2cm;

Over-reported : self-reported – measured ≥ 2cm;

Table 5.4 Mean differences and intra-class correlation coefficients of waist circumference between measured and self-reported values by gender, age, weight status and school type

Waist circumference	Measured*	Self-reported*	Mean differences of Self-reported & Measured	p-value of the mean differences	ICC (95% CI) [Ψ]
All (n=1226)	65.2 (8.9)	67.0 (8.9)	1.7 (4.5)		0.86 (0.80 – 0.89)
Sex					
Boys (n=515)	66.9 (9.9)	69.6 (9.7)	2.6 (4.4)	<0.001 [†]	0.87 (0.72 – 0.93)
Girls (n=711)	64.0 (7.9)	65.1 (7.7)	1.1 (4.5)		0.83 (0.79 – 0.86)
Age (yrs)					
6 – 8 (n=160)	56.5 (8.8)	58.7 (8.8)	2.2 (4.1)	0.010 [‡, a]	0.86 (0.74 – 0.92)
9 – 10 (n=134)	61.6 (8.8)	64.5 (8.6)	2.9 (4.8)		0.81 (0.60 – 0.89)
11 – 12 (n=225)	65.1 (9.1)	66.9 (9.1)	1.7 (4.5)		0.86 (0.80 – 0.91)
13 – 14 (n=232)	67.3 (7.1)	68.9 (7.6)	1.5 (4.8)		0.77 (0.69 – 0.83)
15 – 16 (n=293)	68.1 (7.3)	69.6 (7.9)	1.5 (4.3)		0.82 (0.76 – 0.87)
17 – 18 (n=182)	68.3 (6.9)	69.5 (7.0)	1.1 (4.3)		0.80 (0.74 – 0.85)
Weight status					
Normal (n=972)	62.6 (6.8)	64.6 (7.3)	2.0 (4.3)	<0.001 [‡, b]	0.78 (0.66 – 0.85)
Overweight (n=162)	72.6 (7.3)	73.5 (7.9)	0.9 (4.7)		0.81 (0.74 – 0.86)
Obese (n=92)	80.3 (8.4)	80.3 (8.7)	0.0 (5.2)		0.82 (0.74 – 0.88)
School type					
Primary (n=453)	61.0 (9.8)	63.2 (9.6)	2.2 (4.6)	0.011 [†]	0.87 (0.78 – 0.91)
Secondary (n=773)	67.7 (7.3)	69.2 (7.6)	1.5 (4.4)		0.81 (0.75 – 0.85)

[Ψ] ICC: intraclass correlation coefficient, *mean(sd)

[†] Student's t-test ; [‡] One-way ANOVA.

[a] Post Hoc multiple comparisons with Bonferroni adjustment showed that the age group 9 – 10 was significantly greater in measured – self-reported WC than the age groups of 15 – 16 (p=0.042) and 17 – 18 (p=0.011).

[b] Post Hoc multiple comparisons with Bonferroni adjustment showed that the normal weight group was significantly greater in measured – self-reported WC than the overweight group (p=0.006) and obese group (p<0.001).

Of all children, 38(3.1%) children were classified as having a clustering of CMRFs including 19(3.8%) boys and 19 (2.7%) girls (Table 5.2). The gender-specific AUC-ROCs of both MWC and SRWC for identifying a clustering of CMRFs and overweight/obesity in children are presented in Table 5.5, Figure 5.2 and Figure 5.3. The AUC-ROCs of self-reporting values ranged from 0.76 - 0.84. Using the method suggested by DeLong (DeLong, DeLong, & Clarke-Pearson, 1988) to compare the AUC-ROCs between MWC and SRWC revealed that the AUC-ROCs of MWC were significantly higher than SRWC, except for girls in identifying a clustering of CMRFs. The gender-specific values which were based on the SRWC values, exhibited moderately high to high sensitivity (68% to 84%) and specificity (70% to 82%) in classifying children with a clustering of CMRFs and overweight/obesity.

Table 5.5 Comparison on diagnostic ability between measured and self-reported waist circumference for classifying a clustering of cardiometabolic risk factors (CMRFs)* and overweight/obesity status

	AUC-ROC (95% CI) $^{\Psi}$	p-value †	Sensitivity	Specificity
Clustering of CMRFs				
Boys				
Measured WC	0.84 (0.76 – 0.92)	0.004	0.79 (0.54 – 0.94)	0.82 (0.79 – 0.86)
Self-report WC	0.76 (0.68 – 0.84)		0.68 (0.43 – 0.87)	0.70 (0.66 – 0.74)
Girls				
Measured WC	0.88 (0.83 – 0.94)	0.206	0.84 (0.60 – 0.97)	0.77 (0.74 – 0.81)
Self-report WC	0.83 (0.76 – 0.90)		0.84 (0.60 – 0.97)	0.72 (0.68 – 0.75)
Overweight / obese				
Boys				
Measured WC	0.89 (0.86 – 0.92)	<0.001	0.80 (0.72 – 0.86)	0.82 (0.77 – 0.85)
Self-report WC	0.84 (0.80 – 0.88)		0.74 (0.66 – 0.81)	0.78 (0.74 – 0.82)
Girls				
Measured WC	0.88 (0.85 – 0.92)	0.002	0.76 (0.68 – 0.83)	0.87 (0.84 – 0.89)
Self-report WC	0.84 (0.79 – 0.88)		0.77 (0.69 – 0.84)	0.82 (0.79 – 0.85)

* Clustering of cardiometabolic risk factors (CMRFs) was definied as 3 or more of the followings:
(1) Waist circumference $\geq 90^{th}$ percentile (age and sex specific);
(2) Triglyceride $\geq 90^{th}$ percentile (age and sex specific);
(3) HDL-C $\leq 10^{th}$ percentile (age and sex specific);
(4) fasting blood glucose $\geq$ 5.6 mmol/L
(5) either Systolic BP or diastolic BP $\geq 90^{th}$ percentile (age, sex and height specific);
$^{\Psi}$ Area under the receiver operating characteristic curve;
† p-value testing the statistical significance of the difference between the AUCs of measured and self-reported WC

Figure 5.2 Receiver operating characteristic curves for classifying a clustering of cardiometabolic risk factors by measured and self-reported waist circumference in boys & girls

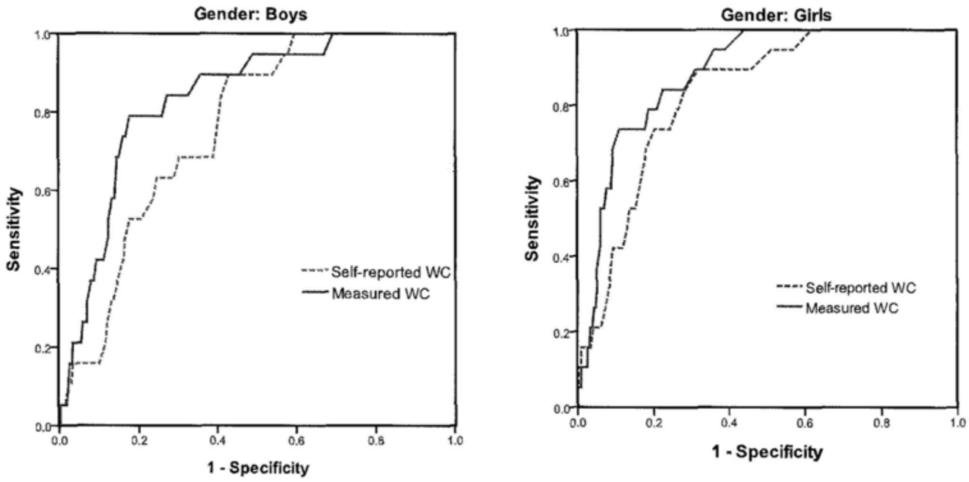
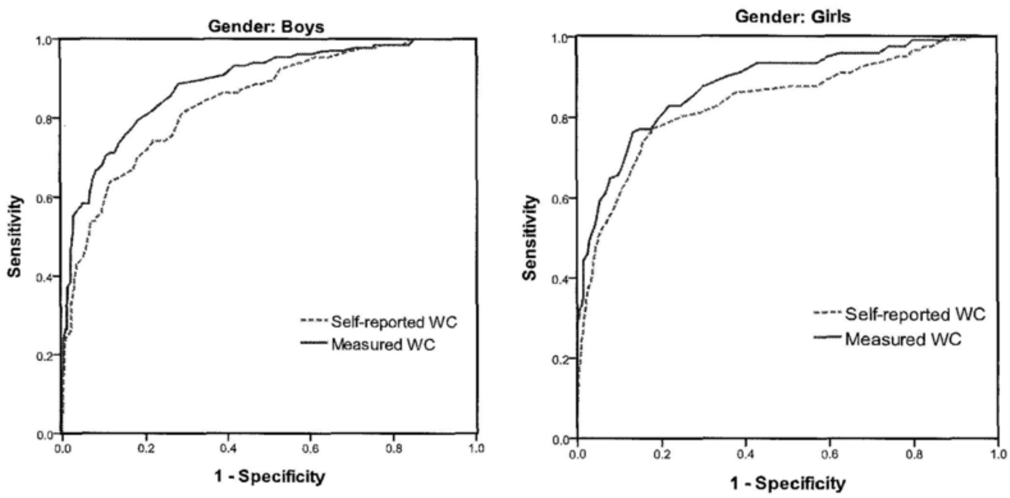


Figure 5.3 Receiver operating characteristic curves for classifying overweight/obesity by measured and self-reported waist circumference in boys & girls



DISCUSSION

The agreement of waist circumference between self-reported and measured values

The aims of this study were two-fold: 1) to assess agreement of WC between self-reported and measured values and 2) to evaluate the diagnostic ability of SRWC in classifying a clustering of CMRFs and overweight/obese status in children. Children/parents were not provided with any protocols or training for measuring SRWC. The results showed that the agreement of WC between measured and self-reported values ranged from substantial to almost perfect ICC for all children. We also found that within subjects mean differences between MWC and SRWC values were small ranging from 0.0 to 2.9 cm (Table 5.4) and more than one third of boys and two-fifths of girls could report their WC values with less than 2 cm differences when compared to measured values. We considered the discrepancy of WC less than 2cm between measured and self-reported values to be within the expected measurement variability. Finding substantial to almost perfect correlation in our results, suggests that SRWC could be used as a screening tool by laypersons without instructions and specific training in WC measurement techniques particularly in population and epidemiological research settings.

We found that the majority of children tended to over-report their WC. Over-reporting WC was observed in almost all groups classified by gender, age, weight status and school type (Table 5.3). Reasons for over-reporting WC are unclear but could relate to the likelihood that children will spontaneously measure their WC at either umbilical level or superior iliac crest, rather than between the lowest rib and the superior border of the iliac crest at the mid-axillary line, over clothing rather than on bare skin without clothing, and during inhalation rather than during exhalation. Other possible factors could relate to self-measurement being undertaken after a meal rather after an eight hour fast or the measuring tape has not been kept snug over the skin. When we compared the mean differences of MWC and SRWC values within different gender, weight status and school type groups, we found that boys, children with normal weight status and primary school/younger age children had significantly higher mean differences than girls, overweight/obese children and secondary school/older age children respectively (Table 5.4). Girls, overweight/obese children and secondary school/older age children may tend to report their narrowest WC, as they may be more aware of their body images such as waist circumference than boys and children with normal weight status. The primary school /younger age children may report their WC with their parents' assistance. Without the provision of a WC measurement protocol in this study, some parents may have measured or estimated their children's WC based on the child's WC when buying trousers or other clothing. However, most trousers designed for younger children have an elasticated or partly elasticated waist. Often parents do not need to measure their children WC very accurately and they may tend to overestimate the WC to ensure the trousers would fit as the child continues to grow. To improve the accuracy of WC measurements, a standardized protocol including WC measurement location, posture, phase of respiration, and time since last meal is needed. An expert panel convened by the International Chair on Cardiometabolic Risk recommended using bony landmarks, for example, the midpoint between the lower border of the rib cage and the iliac crest (World Health Organization, 2008) or the superior border of the iliac crest (National Institutes of Health, 2000) for WC measurement. They argued that WC measurements based on bony landmarks could also be easier for both health professionals and lay persons, improve the reliability and minimize measurement error (Agarwal et al., 2009; Ross, et al., 2008).

The diagnostic ability of SRWC for classifying children with a clustering of CMRFs and overweight/obese status

We attempted to examine the diagnostic ability of SRWC in classifying a clustering of CMRFs and overweight/obese status using AUC-ROCs compared to MWC. The results showed that the AUC-ROCs of SRWC were statistically significantly smaller than MWC. However, this significant difference may reflect our large sample size rather than implying that SRWC lacks utility as a diagnostic tool. Despite the absence of a standardized protocol for children/parents to report children's WC, the AUC-ROCs values for SRWC were still acceptable to excellent (0.76 to 0.84) according to Hosmer and Lemeshow (Hosmer & Lemeshow, 2000). These results suggest that SRWC could have value as a screening tool for classifying clustering of CMRFs and overweight /obesity status in our population. A recent review (Ross, et al., 2008) has argued that different WC measurement protocols would not alter the association between WC and morbidity or mortality substantially because of the high collinearity between different WC measurement sites.

Limitations

A relatively high proportion of children who participated in this study did not report their WC. Reasons for not reporting their WC are not known but the demographics of this group did not differ significantly from the children included in the analysis (Table 5.1). One possible reason is that WC is not as common as body weight to be recorded. The Hong Kong Student Health Service (SHS) Centres yet have not used WC as a measurement tool to identify children with obesity status and WC has not been very popular among laypersons for assessing overweight/obesity status. This may reflect that in the past there have been few WC reference charts available for families to identify central obesity in their children. Age and gender specific WC reference values and the cut-offs are now available for predicting cardiovascular risk in a number of localities (Eisenmann, 2005; Fernandez, Redden, Pietrobelli, & Allison, 2004; Li, Ford, Mokdad, & Cook, 2006; Li, Graubard, & Korn, 2010; Liu et al., 2010; Messiah, Arheart, Lipshultz, & Miller, 2008) including Hong Kong (Ng, et al., 2007; Sung, et al., 2007) Medical and health professionals could do more to promote awareness of these WC cut-off reference values to the general public. A specially designed age- and gender-specific measuring tape with WC cut-off reference values for predicting CMRFs has been developed for Hong Kong children (Sung, R.T.Y. 2008, Press Conference data). Such a tape measure, with CMRFs cutoff marks, could be easier for children and their parents to use and interpret.

In the absence of any widely accepted definition for outliers, we adopted a commonly used cutoff for excluding outliers in this study. However, it can be argued that exclusion of outliers is not appropriate for a study aiming to demonstrate the agreement of SRWC with MWC and the diagnostic ability of SRWC to classify children having a clustering of CMRFs and overweight/obese status. An age- and sex-specific *a-priori* algorithm could be developed to remove outliers prior to analysis e.g. errors such as reporting inches instead of centimeters might be readily identifiable and biologically implausible waist to height ratios. We had relatively few outliers (1.7%) in this study (Figure 5.1). We believe that exclusion of these outliers did not significantly affect our results. As noted earlier, we did not document in the questionnaire as to how the SRWC values were obtained. Such information may provide insight for future studies.

CONCLUSION

SRWC provides an alternative to MWC and could be an effective screening tool for classifying children who have a clustering of CMRFs and overweight/obesity status, at least from a population perspective. Given the increasing prevalence of obesity among children and adolescents and the associated increase in healthcare costs, SRWC could be used in community settings and epidemiological studies for screening children when cost, privacy and other concerns preclude the use of other more accurate obesity assessment tools. The Hong Kong SHS Centres could consider adding WC to its routine annual measurements of children.

CHAPTER 6

THE EFFECT OF PUBERTAL STAGE ON THE PREDICTION OF CARDIOMETABOLIC RISK FACTORS

Preface

This Chapter presents the association between the pubertal stage and CMRFs and the effect of pubertal stage on the prediction of cardiometabolic risks. We have found pubertal stage was significantly associated with some of the CMRFs in boys and girls including large WC, high triglyceride levels, high blood pressure (BP), overweight and obesity in boys and large WC and high BP in girls. Pubertal stage was also found to have a moderating effect on the prediction of CMRFs by BMI and WC. By hierarchical regression analyses, there were significant interactions between pubertal stage and BMI as well as pubertal stage and WC for predicting cardiometabolic risk by BMI and WC respectively. These results were the first to reveal the moderating effect of puberty on the prediction of cardiometabolic risk by BMI or WC in both boys and girls.

INTRODUCTION

Puberty is a stage of complex physiological and hormonal changes that influence the growth and development of children. Body composition during puberty is a marker of metabolic changes that occurs during this period of growth (Siervogel et al., 2003) and may be an important determinant of future health and cardiovascular risk factors in adulthood (Guo et al., 2000; Guo, Wu, Chumlea, & Roche, 2002; Siervogel et al., 2000; Wisemandle, Maynard, Guo, & Siervogel, 2000). Various metabolic changes occur in parameters such as insulin sensitivity

(Ball et al., 2006; Katon, Flores, & Salmerón, 2009; Moran, et al., 1999), blood pressure (Daniels et al., 1996; Leccia et al., 1999), BMI (Katon, et al., 2009) and lipid levels (Tell, Mittelmark, & Vellar, 1985).

During puberty, both sexes experience rapid increases in total body fat, although the proportion of body fat increases more slowly in boys as a result of a simultaneous rapid increase in fat free mass (Siervogel, et al., 2000). Among obese children ages 8 to 13 years, 33% of boys and 40% of girls continued to be obese as adults, whereas for obese adolescences aged 13 to 18, 50% of male and 66% of females remained obese as adults (Guo, et al., 2002). Thus, monitoring body composition during puberty is important because many aspects of body composition during this period are predictive of subsequent measures of these traits in adulthood (Guo, et al., 2000; Guo, et al., 2002).

The complex changes that underlie puberty may affect certain parameters including BMI, BP, insulin sensitivity and lipid levels. Using a dichotomous classification, pubertal girls and boys have been found to have unfavorable BMI, WC, %BF, triglyceride and HDL levels compared to prepubertal counterparts (Katon, et al., 2009). Several studies have shown that puberty is positively associated with BP (Chen & Wang, 2008; Chen & Wang, 2009; Li, Huang, Cruz, & Goran, 2006). Pubertal girls have higher BP than prepubertal girls and this is mediated in large part through the effect of increased body size during puberty. No relationship between BP and puberty has been observed in boys (Daniels, et al., 1996; Leccia, et al., 1999).

Aims of the study

Puberty has a complex, entwined relationship with the various CMRFs. Thus, it is important to examine different pubertal stages when studying differences in CMRFs parameters among Hong Kong children, particularly those at high risk of developing cardiometabolic complications. Pubertal development and CMRFs may exhibit significant inter-racial variations and results from one ethnic group may not be inferred to another. To the best of our knowledge, no previous attempt has been made to investigate the associations between pubertal stages and CMRFs among Hong Kong Chinese children. Therefore, the aims of this study were to examine the associations between pubertal stages and CMRFs in Hong Kong Chinese children and to explore the effect of pubertal stage on the prediction of cardiometabolic risk by body mass index and by waist circumference.

Objectives of the study were to:

1) Investigate the associations between pubertal stages and CMRFs.
2) Investigate the effect of pubertal stage on the prediction of cardiometabolic risk by BMI.
3) Investigate the effect of pubertal stage on the prediction of cardiometabolic risk by WC.

METHODS, PROCEDURES AND STATISTICAL ANALYSES

Methods, procedures and statistical analyses on this chapter have been reported in Chapter 3 methods, procedures and statistical analysis.

RESULTS

Demographic and clinical characteristics of the participants

Of 2088 children aged 6 to 18 years, 1985 (95.1%) children completed the Tanner pubertal self-reported questionnaire (Fig 6.1). The clinical characteristics of those children that completed the Tanner pubertal self-reported questionnaire and those that did not were similar (Table 6.1). The demographic and clinical characteristics, including Tanner pubertal stages, of boys and girls are illustrated in Table 6.2.

Fig 6.1 Flow chart showing the recruitment of participants who completed Tanner pubertal self-reported questionnaire

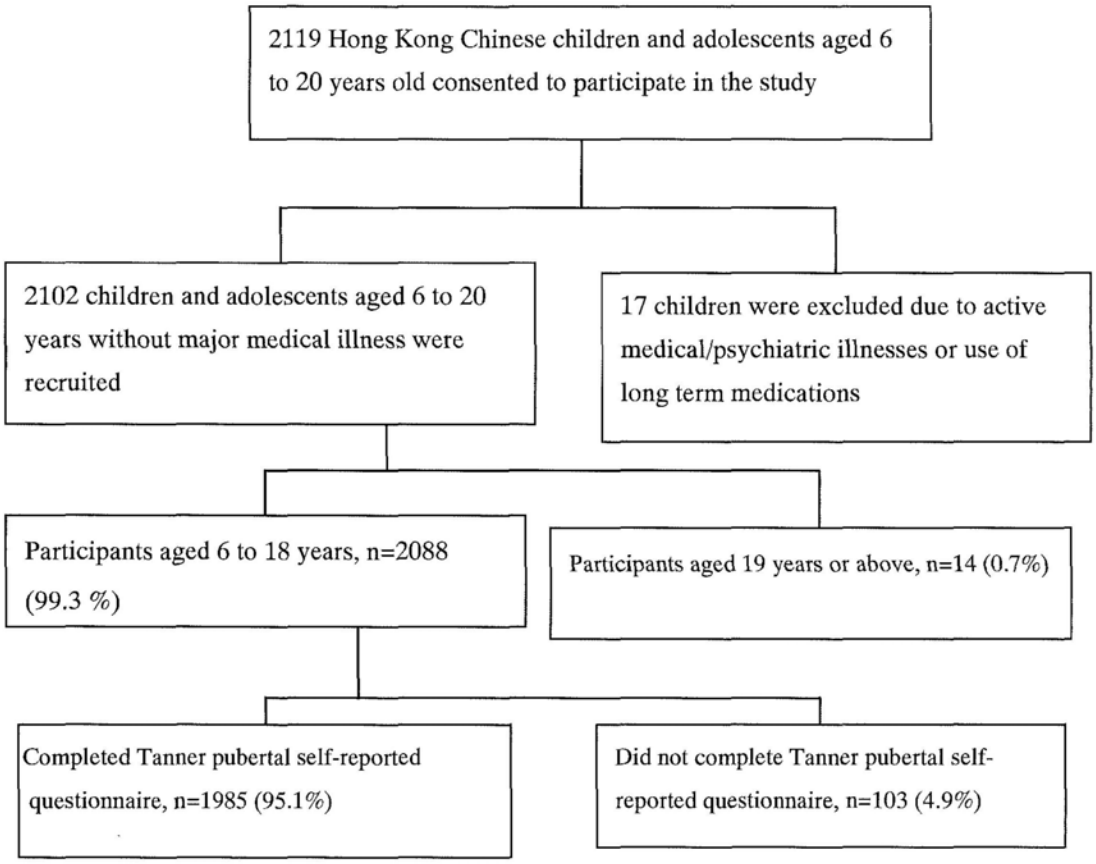


Table 6.1 Demographic and clinical characteristics of those children who completed and those who did not complete the pubertal assessment questionnaire

Characteristics	Not completed (n=103)	Completed (n=1985)
Sex $^{\Psi}$		
Male	56 (54.4%)	828 (41.7%)
Female	47 (45.6%)	1157 (58.3%)
Age (years)	12.5 (3.5)	13.3 (3.3)
Weight (kg)	40.0 (16.7)	44.8 (13.2)
Height (cm)	144.9 (19.4)	152.3 (14.9)
Body Mass Index (kg/m^2)	18.4 (3.5)	18.9 (3.3)
Waist circumference (cm)	63.9 (9.8)	65.0 (8.9)
Systolic blood pressure (mmHg)	108.4 (11.2)	109.8 (11.4)
Diastolic blood pressure (mmHg)	63.3 (8.3)	66.8 (8.3)
HDL-C (mmol/L)	1.7 (0.4)	1.6 (0.3)
LDL-C (mmol/L)	2.2 (0.7)	2.2 (0.6)
Triglyceride (mmol/L) †	0.8 (0.6 – 1.0)	0.7 (0.6 – 1.0)
Fasting plasma glucose (mmol/L)	4.7 (0.3)	4.7 (0.4)
Obesity status $^{\Psi}$		
Normal	82 (79.6%)	1591 (80.2%)
Overweight	15 (14.6%)	257 (12.9%)
Obese	6 (5.8%)	137 (6.9%)

Data marked with † were presented as medians (interquartile ranges) and with $^{\Psi}$ as frequencies (%), all others were presented as means (standard deviations).

Table 6.2 Demographic and clinical characteristics by gender of 1985 Hong Kong Chinese school children aged 6-18 years who completed the pubertal assessment questionnaire

Characteristics	Male (n=828)	Female (n=1157)
Age (years)	12.9 (3.2)	13.6 (3.3)
Weight (kg)	46.6 (14.9)	43.5 (11.7)
Height (cm)	154.3 (17.1)	150.9 (13.0)
Body Mass Index (kg/m^2)	19.1 (3.5)	18.7 (3.1)
Waist circumference (cm)	66.5 (9.9)	63.9 (7.9)
Systolic blood pressure (mmHg)	113.6 (12.1)	107.1 (9.9)
Diastolic blood pressure (mmHg)	66.7 (8.7)	66.8 (8.0)
HDL-C (mmol/L)	1.6 (0.3)	1.6 (0.3)
LDL-C (mmol/L)	2.1 (0.6)	2.2 (0.6)
Triglyceride (mmol/L) †	0.7 (0.6 – 1.0)	0.7 (0.6 – 1.0)
Fasting plasma glucose (mmol/L)	4.8 (0.4)	4.7 (0.3)
Obesity status $^{\Psi}$		
Normal	623 (75.2%)	968 (83.7%)
Overweight	129 (15.6%)	128 (11.1%)
Obese	76 (9.2%)	61 (5.3%)
Puberty (Tanner stage) $^{\Psi}$		
1	205 (24.8%)	178 (15.4%)
2	177 (21.4%)	151 (13.1%)
3	129 (15.6%)	219 (18.9%)
4	284 (34.3%)	464 (40.1%)
5	33 (4.0%)	145 (12.5%)

Data marked with † were presented as medians (interquartile ranges) and with $^{\Psi}$ as frequencies (%), all others were presented as means (standard deviations).

Association between pubertal stage and CMRFs

For boys, puberty was significantly associated with several CMRFs, including large WC ($p=0.007$), high triglyceride levels ($p=0.011$), high BP ($p=0.001$). Puberty was also significantly associated with overweight ($p<0.001$) and obesity ($p<0.001$) (Table 6.3). The highest rate of children with these CMRFs was found in the prepubertal group. For girls, pubertal stage was significantly associated with large WC ($p=0.005$) and high BP ($p=0.033$) (Table 6.3). The highest rate of children with large WC was in the postpubertal group and the highest rate with high BP was in the prepubertal group.

Cardiometabolic risk score α and cardiometabolic risk β

Since only a small number of children (n=54) were identified with CMRFs clustering, we were having inadequate power to explore the moderator effect of pubertal stage on the prediction of clustering of CMRFs by WC or BMI. We adopted a summary risk score to quantify the cardiometabolic risk for examining the moderator effect. Two cardiometabolic risk scores, α and β, were predicted in the analyses. Cardiometabolic risk score α is reported in Table 6.4 and 6.5 and were composed of all components of the cardiometabolic risk score including z score sex specific, age adjusted WC, systolic BP and diastolic BP, fasting plasma glucose, triglyceride, LDL cholesterol and minus z score of HDL cholesterol. Cardiometabolic risk score β is reported in Table 6.4a and 6.5a and represents the sum of all components except WC.

The moderator effect of pubertal stage on the prediction of cardiometabolic risk by waist circumference

For the prediction of cardiometabolic risk score α by WC in the hierarchical regression analyses (Table 6.4), the variables were WC, pubertal stage and the interaction of WC and pubertal stage. In Model 1, WC explained a significant proportion of the variance in cardiometabolic risk score α in both boys (36.1%) and girls (25%). When puberty was entered in Model 2, it accounted for a significant increase in variance in both genders, explaining 40% of the variance in boys and 30.5% in girls. When the interaction of WC and puberty was entered in Model 3, a significant increase of the variance was accounted for in both genders, explaining 40.6% of the variance in boys and 30.9% in girls.

Cardiometabolic risk score β included all components of risk score α except WC was used to present the hierarchical sequence (Table 6.4a). In Model 1, WC could explain a significant proportion of the variance in cardiometabolic risk score β in both boys (14.7%) and girls (6.3%). In Model 2, puberty further increased the variance significantly in both genders, explaining 16.1% of the variance in boys and 7.8% in girls. When the interaction of WC and puberty was included in Model 3, there was a significant increase in variance in boys, explaining 17.1% of the variance. For girls, the increase in variance was not significant, it was nevertheless marginally close to statistical significance (p=0.07), explaining 8.3% of the variance.

Table 6.3: Association between pubertal stage and cardiometabolic risk factors (CMRFs)

	Male (n=828)				Female (n=1157)			
	Pre-pubertal (n=205)	Pubertal (n=306)	Late /Post-pubertal (n=317)	p-value *	Pre-pubertal (n=178)	Pubertal (n=370)	Late/ Post-pubertal (n=609)	p-value *
Age (y) [median (IQR)]	9.5 (8.3 – 11.0)	12.1 (10.5 – 13.5)	16.0 (15.1 – 17.2)		8.4 (7.6 – 9.3)	12.1 (10.8 – 13.8)	15.9 (14.7 – 17.3)	
Cardiometabolic risk factors								
large waist circumference [1]	48 (23.4%)	59 (19.3%)	41 (12.9%)	0.007	18 (10.1%)	55 (14.9%)	120 (19.7%)	0.005
High triglyceride [2]	28 (14.4%)	29 (9.7%)	20 (6.3%)	0.011	15 (9.0%)	46 (12.5%)	55 (9.0%)	0.190
Low HDL [3]	18 (9.2%)	28 (9.3%)	26 (8.2%)	0.873	17 (10.2%)	26 (7.1%)	35 (5.7%)	0.128
High fasting blood glucose [4]	3 (1.5%)	7 (2.3%)	10 (3.2%)	0.573	0 (0.0%)	9 (2.4%)	7 (1.1%)	0.065
High blood pressure [5]	58 (28.3%)	62 (20.3%)	46 (14.5%)	0.001	32 (18.0%)	62 (16.8%)	72 (11.8%)	0.033
Clustering of the above CMRFs †	9 (4.6%)	12 (4.0%)	10 (3.2%)	0.705	3 (1.8%)	10 (2.7%)	10 (1.6%)	0.495
Overweight / obese [6]	77 (37.6%)	79 (25.8%)	49 (15.5%)	<0.001	28 (15.7%)	57 (15.4%)	104 (17.1%)	0.768
Obese [7]	37 (18.0%)	30 (9.8%)	9 (2.8%)	<0.001	9 (5.1%)	21 (5.7%)	31 (5.1%)	0.915

(1) Waist circumference ≥ 90th percentile (age and sex specific);
(2) Triglyceride ≥ 90th percentile (age and sex specific);
(3) HDL-C ≤ 10th percentile (age and sex specific);
(4) Fasting blood glucose ≥ 5.6 mmol/L
(5) Systolic BP/diastolic BP ≥ 90th percentile (age, sex and height specific).
† Clustering of cardiometabolic risk factors (CMRFs) was defined as 3 or more of the above 5 CMRFs.
(6) BMI ≥ 85^{th} percentile (age and sex specific)
(7) BMI ≥ 95^{th} percentile (age and sex specific)
* p-value testing the statistical significance of the association between each of the CMRFs and pubertal stage.

Table 6.4 Hierarchical multiple regression analyses of the moderator effect of pubertal stage on the prediction of a cardiometabolic risk Score α by waist circumference.

Cardiometabolic Risk Score α *	**Boys (n=828)**					**Girls (n=1157)**				
	B	SE	p	R^2	p (ΔF)	B	SE	p	R^2	p (ΔF)
Model 1				0.361	<0.001#				0.250	<0.001#
WC Z-score	1.935	0.091	<0.001			1.452	0.074	<0.001		
Model 2				0.400	<0.001				0.305	<0.001
Waist circumference (z score)	2.134	0.092	<0.001			1.931	0.088	<0.001		
Pubertal stage:										
Pre-pubertal (ref)										
Pubertal	-0.902	0.231	<0.001			-1.138	0.240	<0.001		
Late/Post-pubertal	-1.703	0.237	<0.001			-2.267	0.256	<0.001		
Model 3				0.406	0.010				0.309	0.035
Waist circumference (z score)	1.730	0.164	<0.001			2.296	0.220	<0.001		
Pubertal stage:										
Pre-pubertal (ref)										
Pubertal	-0.721	0.237	0.002			-1.628	0.344	<0.001		
Late/Post-pubertal	-1.583	0.243	<0.001			-2.727	0.338	<0.001		
Interaction terms:										
ZWC * Pubertal	0.651	0.220	0.003			-0.666	0.270	0.014		
ZWC * Late/Post-pubertal	0.506	0.236	0.032			-0.295	0.252	0.240		

WC Z-score: waist circumference Z score;
B: un-standardized regression coefficient;
SE: standard error;
p: p-value testing the significance of the regression coefficient;
R^2: variance explained by the regression model;
p (ΔF): p-value testing the significance of F change from the preceding model (# the preceding model of model 1 included only the intercept tern);
ref: reference group of the categorical variable that analyzed by creating dummy variables;
* Cardiometabolic Risk Score α = Sum of components' z score: components of cardiometabolic risk score α include z-score of sex-specific, age-adjusted waist circumference, systolic and diastolic blood pressure (also height-adjusted), fasting plasma glucose, triglyceride and low-density lipoprotein cholesterol (LDL-C), and minus z-score of sex-specific age-adjusted high-density lipoprotein cholesterol (HDL-C).

Table 6.4a Hierarchical multiple regression analyses of the moderator effect of pubertal stage on the prediction of a cardiometabolic risk Score β by waist circumference.

Cardiometabolic Risk Score β *	**Boys (n=828)**					**Girls (n=1157)**				
	B	SE	p	R^2	p (△F)	B	SE	p	R^2	p (△F)
Model 1				0.147	<0.001[#]				0.063	<0.001[#]
Waist circumference (z score)	1.025	0.087	<0.001			0.611	0.070	<0.001		
Model 2				0.161	0.001				0.078	<0.001
WC Z-score	1.119	0.091	<0.001			0.820	0.085	<0.001		
Pubertal stage:										
Pre-pubertal (ref)										
Pubertal	-0.574	0.227	0.012			-0.473	0.232	0.042		
Late/Post-pubertal	-0.846	0.233	<0.001			-0.982	0.246	<0.001		
Model 3				0.171	0.008				0.083	0.071
Waist circumference (z score)	0.723	0.161	<0.001			1.205	0.212	<0.001		
Pubertal stage:										
Pre-pubertal (ref)										
Pubertal	-0.394	0.233	0.091			-0.968	0.331	0.004		
Late/Post-pubertal	-0.715	0.238	0.003			-1.438	0.326	<0.001		
Interaction terms:										
ZWC * Pubertal	0.667	0.216	0.002			-0.599	0.261	0.022		
ZWC * Late/Post-pubertal	0.458	0.231	0.048			-0.373	0.242	0.124		

WC Z score: waist circumference Z score;
B: un-standardized regression coefficient;
SE: standard error;
p: p-value testing the significance of the regression coefficient;
R^2: variance explained by the regression model;
p (△F): p-value testing the significance of F change from the preceding model ([#] the preceding model of model 1 included only the intercept tern);
ref: reference group of the categorical variable that analyzed by creating dummy variables;
* Cardiometabolic risk score β included all components of risk score α except waist circumference

Table 6.5 Hierarchical multiple regression analyses of the moderator effect of pubertal stage on the prediction of a cardiometabolic risk Score α by body mass index.

Cardiometabolic Risk Score α *	**Boys (n=828)**					**Girls (n=1157)**				
	B	SE	p	R^2	p (△F)	B	SE	p	R^2	p (△F)
Model 1				0.350	<0.001#				0.223	<0.001#
Body mass index (z score)	1.894	0.091	<0.001			1.364	0.075	<0.001		
Model 2				0.374	<0.001				0.261	<0.001
Body mass index (z score)	2.019	0.092	<0.001			1.722	0.088	<0.001		
Pubertal stage:										
Pre-pubertal (ref)										
Pubertal	-0.594	0.235	0.012			-0.460	0.240	0.055		
Late/Post-pubertal	-1.302	0.238	<0.001			-1.622	0.253	<0.001		
Model 3				0.379	0.024				0.268	0.006
BMI Z score	1.747	0.164	<0.001			2.485	0.255	<0.001		
Pubertal stage:										
Pre-pubertal (ref)										
Pubertal	-0.477	0.239	0.046			-1.260	0.346	<0.001		
Late/Post-pubertal	-1.196	0.241	<0.001			-2.340	0.338	<0.001		
Interaction terms:										
ZBMI * Pubertal	0.593	0.224	0.008			-0.903	0.302	0.003		
ZBMI * Late/Post-pubertal	0.177	0.230	0.443			-0.845	0.280	0.003		

BMI Z score : body mass index Z score; B: un-standardized regression coefficient; SE: standard error;
p: p-value testing the significance of the regression coefficient;
R^2: variance explained by the regression model;
p (△F): p-value testing the significance of F change from the preceding model (# the preceding model of model 1 included only the intercept term);
ref: reference group of the categorical variable that analyzed by creating dummy variables;
* Cardiometabolic Risk Score α = Sum of components' z score: components of cardiometabolic risk score α include z-score of sex-specific, age-adjusted waist circumference, systolic and diastolic blood pressure (also height-adjusted), fasting plasma glucose, triglyceride and low-density lipoprotein cholesterol (LDL-C), and minus z-score of sex-specific age-adjusted high-density lipoprotein cholesterol (HDL-C).

Table 6.5a Hierarchical multiple regression analyses of the moderator effect of pubertal stage on the prediction of cardiometabolic risk Score β by body mass index.

Cardiometabolic Risk Score β *	**Boys (n=828)**					**Girls (n=1157)**				
	B	SE	p	R^2	p (△F)	B	SE	p	R^2	p (△F)
Model 1				0.147	<0.001#				0.066	<0.001#
BMI Z score	1.020	0.086	<0.001			0.619	0.069	<0.001		
Model 2				0.155	0.019				0.079	<0.001
Body mass index (z score)	1.076	0.089	<0.001			0.797	0.082	<0.001		
Pubertal stage:										
Pre-pubertal (ref)										
Pubertal	-0.415	0.226	0.067			-0.229	0.224	0.306		
Late/Post-pubertal	-0.647	0.230	0.005			-0.804	0.236	0.001		
Model 3				0.163	0.030				0.084	0.051
Body mass index (z score)	0.811	0.158	<0.001			1.328	0.239	<0.001		
Pubertal stage:										
Pre-pubertal (ref)										
Pubertal	-0.303	0.230	0.189			-0.801	0.324	0.014		
Late/Post-pubertal	-0.549	0.233	0.019			-1.314	0.316	<0.001		
Interaction terms:										
ZBMI * Pubertal	0.561	0.216	0.010			-0.675	0.283	0.017		
ZBMI * Late/Post-pubertal	0.192	0.222	0.389			-0.565	0.262	0.031		

BMI Z score : body mass index Z score; B: un-standardized regression coefficient;
SE: standard error;
p: p-value testing the significance of the regression coefficient;
R^2: variance explained by the regression model;
p (△F): p-value testing the significance of F change from the preceding model (# the preceding model of model 1 included only the intercept tern);
ref: reference group of the categorical variable that analyzed by creating dummy variables;
* Cardiometabolic risk score β included all components of risk score α except waist circumference.

The moderator effect of pubertal stage on the prediction of cardiometabolic risk by BMI

For the prediction of cardiometabolic risk score α in the hierarchical regression analyses (Table 6.5), the variables were BMI, pubertal stage and interaction of BMI and pubertal stage. In Model 1, BMI explained a significant proportion of the variance in cardiometabolic risk score α in both boys (35%) and girls (22.3%). Pubertal stage was entered in Model 2 and accounted for a significant increase in variance in both genders, explaining 37.4% of the variance in boys and 26.1% in girls. When the interaction of BMI and puberty was entered in Model 3, there was a significant increase of the variance in both genders, explaining 37.9% of the variance in boys and 26.8% in girls.

Cardiometabolic risk score β included all components of risk score α except WC was used to present the hierarchical sequence (Table 6.5a). In Model 1, BMI could explain a significant proportion of the variance in cardiometabolic risk score β in both boys (14.7%) and girls (6.6%). In Model 2, puberty further increased the variance significantly in both genders, explaining 15.5% of the variance in boys and 7.9% in girls. When the interaction of BMI and puberty was included in Model 3, the increase in variance remained significant in boys, explaining 16.3% of the variance. For girls, the increase in variance was only marginally not significant, explaining 8.4% of the variance.

DISCUSSION

Our study examined the association between puberty and CMRFs and the effect of puberty from a cross sectional cohort of 1985 children. Among boys, puberty was significantly associated with some of the CMRFs, including large WC, high triglyceride levels, high BP, overweight and obesity, with the highest rate of these CMRFs among the prepubertal group. Among girls, puberty was significantly associated with large WC and high BP, with the highest rate of these risk factors in late/post pubertal and prepubertal group respectively. Pubertal stage was also found to have a moderating effect on the prediction of cardiometabolic risk by WC or BMI. The models that included the interaction of WC and puberty and the interaction of BMI and puberty both had significant increase in proportion of the variance explained (Table 6.4 & Table 6.5).

In our study population of Hong Kong Chinese children, we found a higher rate of CMRFs among prepubertal boys. This is a unique and interesting finding in that most studies found an association between puberty and unfavorable changes of metabolic profile including greater WC, increase in insulin resistance, increase in BP and worsening lipid profiles (Ball, et al., 2006; Daniels, et al., 1996; Katon, et al., 2009; Leccia, et al., 1999; Moran, et al., 1999). The higher rate of the some CMRFs for boys in their prepubertal stage may imply that the cutoffs of CMRFs have been defined lower than that stage and therefore overclassified some boys with having CMRFs. Although there was no significant association found between pubertal stage and CMRFs clustering, this may be due to small sample size of cases. Further study warrants an investigation of the CMRFs cutoffs and the relationship between pubertal stage and CMRFs clustering for Hong Kong Chinese children.

Worth noting, we found higher rate of large WC among prepubertal boys with a decreasing trend towards late and post puberty, but the reverse trend in girls. The gender difference we observed in the association between WC and pubertal stage may be attributable to the differences in female and male change of body composition and hormones. In the prepubertal stage, the proportions of adipose tissue and fat-free mass in boys and girls are similar with body fat counts of about 15% and 19% muscle. In contrast, during puberty, girls have on average greater gain in fat mass than fat-free mass, whereas boys gain more fat-free mass than fat mass (Mahan & Escott-Stump, 1996). This is mainly caused by the increase in testosterone and IGF-1, which are both muscle building hormones, in pubertal boys (Arslanian & Kalhan, 1996; Griggs et al., 1989). Consequently, female adults have about 22% body fat compared with an average of 15% in male adults (Mahan & Escott-Stump, 1996). As boys can retain a relative constant fat mass throughout pubertal development while gaining in height, this may explain the lower rate of large WC, overweight and obesity among the post pubertal boys. The greater gain of fat mass in girls during puberty may also account for the higher rate of large WC among post pubertal girls.

Aside from the possible biological mechanisms, it is also of interest to examine how social norms and environmental factors contribute to these results. In a wealthy society like Hong Kong, social norms and expectations dictate our perceptions towards weight and body image. In a local Hong Kong study of secondary school students in form one to three, there was a gender difference in the extent of disagreement between body weight perceptions and actual weight, with the discrepancy more marked in females. More girls than boys considered themselves to be overweight and more boys than girls considered themselves to be underweight. As a result, boys were less likely to engage in weight losing behavior and restrict energy intake (Cheung, Ip, Lam, & Bibby, 2007). This thinking among Hong Kong Chinese children may explain the higher rates of overweight and obesity in boys compared with girls. Our findings are consistent with findings from the Hong Kong Growth Study (2005/06) (So, et al., 2008).

Though the results of our study may not be in line with previous research on the association between puberty and BMI, WC and various metabolic profiles, we would like to point out the subtle differences in the approach of our study compared to theirs. In our study, we tried to explore the association between pubertal stages and individual CMRFs and to examine if the pubertal stage was associated with CMRFs clustering, whereas the other studies looked into the changes of metabolic profile that occurs in different pubertal stages (Ball, et al., 2006; Daniels, et al., 1996; Katon, et al., 2009; Leccia, et al., 1999; Moran, et al., 1999). Therefore, it may not be appropriate to make direct comparisons between the results and our study may shed new light into the relationship between CMRFs and puberty.

Our results are the first to reveal the moderator effect of puberty on the prediction of cardiometabolic risk by WC or BMI in both boys and girls. Predicting cardiometabolic risk score β is statistically more demanding than cardiometabolic risk score α as it removes the WC component, which is a predictor variable in the model, from the risk score. Since, the interaction terms between puberty and WC and between puberty and BMI remain significant in boys and marginally not significant in girls, these findings may suggest that there is moderator effect of pubertal stage on the prediction of cardiometabolic risk β by WC or BMI. That means the prediction of cardiometabolic risk by WC or BMI depends on the stage of puberty. To our knowledge, few existing anthropometry references are able to account for children's pubertal stage. Some studies have demonstrated that adjustment for sexual maturation can affect the estimates of overweight prevalence (Himes, 1999; Wang & Adair, 2001). Further studies are warranted to assess how we can apply this information in clinical practice and to revisit the cut offs for CMRFs which incorporates the pubertal stage of the child in the assessment.

Limitations of the study

Our study used self-reported Tanner stages to categorize the pubertal stages of the study participants. Although a previous study has confirmed the utility of the self-reported pubertal questionnaire, self-reporting of puberty may still be difficult for children to determine their pubertal stage, in particular stages 3 and 4, as the sexual maturation stages are somewhat subjective and there is no exact cut off of the Tanner stages (Chan, et al., 2008). The discrepancies between self-reported and the actual pubertal stage could exist and it may affect the results. For our analysis of the association between pubertal stage and CMRFs, our sample size may not be large enough for identifying children with CMRFs clustering. A further large-scale population study is warranted to detect any causal relationship between puberty and CMRFs.

CONCLUSION

In conclusion, our study provides further evidence showing that CMRFs, including large WC and high BP for both boys and girls and high triglyceride for boys, were associated with puberty. Pubertal stage was also found to have a moderator effect on the prediction of cardiometabolic risk by WC or BMI. These findings have implications for further research into the causal relationship between puberty, obesity and CMRFs.

CHAPTER 7

DISCUSSION AND CONCLUSION

SUMMARY

The increase in overweight/obesity in children has become a major public health concern worldwide. Childhood obesity has been shown to be associated with a clustering of CMRFs including increased WC/BMI, impaired lipid profile, elevated BP, impaired glucose tolerance and insulin resistance. Obese children are likely to remain obese and would retain their CMRFs in adulthood, which may lead to serious health consequences such as type 2 diabetes, cardiovascular diseases and cerebrovascular diseases. Screening of overweight/obesity is an important step to monitor the prevalence of overweight/obesity in children and to develop preventive intervention strategies for overweight/obesity. Therefore, in this thesis we aimed at identifying simple, cheap and convenient overweight/obesity screening tools. We assessed the agreement of SRDBMI and SRWC against MBMI and MWC. The results show that SRDBMI and SRWC demonstrate good consistency with MBMI and MWC. We also used the SRDBMI and SRWC to examine the diagnostic ability of SRDBMI and SRWC to classify children with overweight/obesity and with CMRFs clustering. The results suggest that SRDBMI and SRWC may have value as a screening tool for identifying clustering of CMRFs and overweight/obesity status in our population. Since some of our children were experiencing sexual maturation, we then explored the association between pubertal stage and CMRFs. However, due to the small sample size of children, significant association between pubertal stages and CMRFs clustering was not found. We then examined the effect of pubertal stages on predicting CMRFs by WC and BMI. The results show that pubertal stage has a moderator effect on predicting CMRFs by WC and BMI. The findings have implications on further research into the relationship between puberty, obesity and CMRFs.

Summary of each chapter

Chapter 1 was the introduction and literature review. This chapter briefly described prevalence of childhood obesity worldwide and in Hong Kong, the health impact of childhood obesity, the common obesity assessment methods, the physiological and metabolic changes during puberty and the relationship between obesity and sexual maturation. BMI and WC are simple, accessible, low cost and practical tools for identifying overweight and obesity and have been useful predictors of cardiovascular morbidity and mortality. Self-reported anthropometric measures for identifying overweight/obesity have been used elsewhere both in adults and children. Hence, we developed research questions followed by the study aims and objectives. The primary rationale for conducting this research was to find out if SRDBMI and SRWC can identify children with overweight/obesity and CMRFs clustering. The structure of this thesis was described.

In Chapter 2, we reported on the performance of two self-reported questionnaire between the measured and self-reported score; namely Tanner pubertal self-reported questionnaire with Chinese text and a Chinese self-reported Pubertal Development Scale. These two self-reported pubertal questionnaires were used in subsequent studies to examine the associations between self-reported pubertal stages and CMRFs and explore the moderator effect of pubertal stages on prediction of cardiometabolic risk by BMI and WC (presented in chapter 6).

In Chapter 3, we described the methods and procedures of data collection of the main study named "Sleep duration, neurohormonal dysregulation and obesity in Hong Kong children and adolescents". This chapter included the statistical analyses of different chapters: chapter 2, 4, 5 and 6 of this thesis. The author of this thesis was involved in part of the data collection and data entry and all the data analyses, all report writing of this thesis.

In Chapter 4, we presented the agreement of SRBW, SRBH and SRDBMI with measured values and the diagnostic ability of SRDBMI to classify children with overweight/obesity and CMRFs clustering. The findings suggested that SRBW and SRBH demonstrated good consistency with the assessor measured BW and BH. The SRDBMI classified children with overweight/ obesity and CMRFs clustering satisfactorily.

In Chapter 5, we reported the agreement of SRWC with MWC and its diagnostic ability in classifying children with overweight/obesity and CMRFs clustering. The results showed that the intra-class correlation coefficients for WC between measured and self-reported values ranged from substantial to almost perfect for the children/adolescents. The SRWC was used to assess its diagnostic ability to classify children with central obesity and CMRFs clustering. The findings suggest that SRWC could satisfactorily identify the children with overweight, obesity status and CMRFs clustering, at least from a population perspective.

In Chapter 6, we examined the association between pubertal stages and CMRFs clustering. Although no association was found between the two variables due to the small number of children having CMRFs clustering, we found that puberty was significantly associated with individual CMRFs such as large WC, increased triglycerides, and elevated BP in boys and large WC and elevated blood pressure in girls. We then explored the effect of puberty on the prediction of CMRFs. Results showed that puberty had a significant moderator effect on the prediction of CMRFs by WC or BMI. (See Table 7.1 for summarizing the results of Chapter 2 and 4 to 6).

Table 7.1 Summary of results of Chapter 2 and 4-6

Chapter	Title	Aims	Sample size	Summary of the results
2	Assessing self-reported pubertal stage	To assess the performance of a self-reported Chinese version line-drawing Tanner pubertal questionnaire and PDS against raters' assessment.	Total 354 students (172 boys and 182 girls) responded to the Tanner pubertal questionnaire Total 290 students (129 boys and 161 girls) responded to PDS	The findings from Tanner pubertal questionnaire and PDS suggest that these two questionnaires could be used in certain population based research to obtain a crude assessments of pubertal stage in children/adolescents.
4	Assessing self-reported BW and BH	To assess the agreement of SRBW and SRBH against the measured values. To evaluate whether SRDBMI could appropriately classify our children with overweight/obese status and CMRFs clustering.	Total 1614 children (671 boys and 943 girls)	SRBW and SRBH could be used to estimate MBW and MBH from a population perspective. SRDBMI could be used to classify children with overweight and obesity status and CMRFs clustering from a population perspective.
5	Assessing self-reported WC	To assess the agreement of SRWC against assessor MWC. To evaluate whether SRWC could appropriately classify our children with overweight/obese status and CMRFs clustering.	Total of 1226 children (515 boys and 711 girls)	SRWC could be used to estimate assessor MWC from a population perspective SWC could be used to classify children with overweight and obesity status and CMRFs clustering from a population perspective.
6	The effect of pubertal stage on the prediction of CMRFs	To examine the associations between pubertal stages and CMRFs. To investigate the effect of pubertal stage on the prediction of CMRFs by BMI and WC.	1985 children (828 boys & 1157 girls)	No significant associations between pubertal stages and CMRFs. For boys, large WC, high TG, high BP, overweight and obesity were association with pubertal stage. For girls, large WC and high blood pressure were associated with pubertal stage. Pubertal stage has a significant moderator effect on the prediction of CMRFs by BMI and WC.

Discussion

The prevalence of childhood overweight/obesity has increased significantly in past decades worldwide as well as in Hong Kong. Children with high BMI and larger WC for their age are at much greater risk of the cardiometabolic co-morbidities of overweight/obesity. Studies have reported that both BMI and WC values can equally identify CMRFs (Dalton et al., 2003; Jackson et al., 2002; Ko, Chan, Cockram, & Woo, 1999). Although BMI is commonly used as the measure of overweight/obesity (Cole, et al., 2000), it has drawbacks in defining overweight/obesity children/adolescents during puberty. BMI is unable to differentiate fat-free mass and fat mass during puberty as physical growth, metabolic and hormonal changes vary among children during this period of time (McCarthy et al., 2006, Maynard et al., 2001). Changes in BMI may be attributable to increase in fat-free mass and body height rather than fat mass. Consequently, two children with the same amount of body fat can have different BMI values (McCarthy et al., 2003). In addition, measurement of BMI requires skill, use of well-maintained equipment and accurate calculation of BMI values.

Body fat distribution is an important indicator for cardiometabolic risk. Population studies have found that an excessive upper body or abdominal fat carries an increased risk for obesity-associated cardiometabolic complications including adverse lipropotein and fasting insulin concentration (McCarthy et al., 2006; Caprio S et al., 1996; Kahn, et al., 2005), dyslipidemia and high fasting glucose, as well as high blood pressure (Kelishadi et al., 2007; Daniels et al., 2000). Abdominal fat may also lead to 'fat-induced insulin resistance' during pubertal progression (Freedman et al., 1987; Zimmet et al., 2007).

WC has been found to be a highly sensitive and specific indicator of upper body fat accumulation in children (Taylor et al., 2000) and hence might offer a more sensitive measure of overweight/obesity than BMI (McCarthy and Ashwell, 2006). WC has been recommended as a screening tools and single measure of cardiovascular and metabolic health risks (Klein et al., 2004; Kannel et al., 1991). With only a measuring tape with special designed age and gender specific WC cut-off reference values for predicting CMRFs, a low cost and effective assessment of cardiometabolic risk could be obtained. Furthermore, it is unrelated to height, correlates closely with BMI and total body fat.

For quantifying obesity, it is useful to have a simple, standard and cost-effective screening tool. WC measurement values are relatively simpler to obtain than that of BMI. In review of the limitation of BMI in differentiating lean mass and fat mass and abdominal fat is important to identify 'fat-induced insulin resistance' during pubertal progression (Brambilla, et al., 2006), WC has an advantage over BMI to be used as screening tool for assessing the central obesity in overweight/obesity in children. WC is easier for public to understand than BMI. In this thesis, both SRDBMI and SRWC demonstrate a good consistency with the measured values, at least from the population perspective. SRWC has potential to quantify overweight/obesity in home-assessment and community-assessment in order to increase children/parents' awareness of their children overweight/obesity status and the related health risks as well as population, public health and nutritional epidemiological research as an alternative data collection when cost and time are the constrain of the study.

We validated two self-reported pubertal questionnaires, namely Tanner pubertal self-assessment questionnaire and pubertal development scale for assisting data collection in the sleep study. The Tanner pubertal self-reported questionnaire and the pubertal development scale were published in peer reviewed journals. The Tanner pubertal self-reported questionnaire has been cited by other authors (Azevedo, Brasil, Macedo, Pedrosa, & Arrais, 2009; Dorn & Biro, 2011; Kong, et al., 2010; Lamb, Beers, Reed-Gillette, & McDowell, 2011; Tam et al., 2010), as has the Chinese self-reported pubertal development scale (Sumter, Bokhorst, Miers, Van Pelt, & Westenberg, 2010).

We provided further evidence on the association between pubertal stages and individual CMRFs in both boys and girls. However, we could not find any significant association between puberty and CMRFs clustering due to the small number of children having a clustering of CMRFs. We further investigated the effect of puberty on the prediction of CMRFs. We found that puberty has a moderator effect on the prediction CMRFs by BMI and WC. To the best of our knowledge, no previous study has published such findings. Our findings inform child obesity researchers and experts that they should consider puberty when undertaking research in this area and the need for further understanding of these complex relationships.

Limitations

There are several limitations in this thesis that are worth noting. The study on pubertal self-reported was a cross sectional convenience sample that could result in selection bias. The sleep study (the main study) was also a cross-sectional random sample study, but only 5 primary schools and 6 secondary schools were involved in the study. Therefore, the findings of this thesis may not be representative of the Hong Kong children population. In addition, a cross-sectional design is limited in that the measurement of anthropometric measures and pubertal stage is at one time point only. This means that the study population at the three pubertal stages is represented by different children at a wide range of ages. The three pubertal groups may not be comparable as some children/adolescents may be far apart in age and there may be underlying different social and environmental influences on the different groups. The anthropometric measurements were undertaken by about three main research staff. As there could be measurement variations or errors between raters, it would have been preferable to have conducted inter-rater reliability measurement testing between raters prior to embarking on the study to minimize potential variation between raters.

We found a higher rate of large WC, BP, triglycerides, overweight and obesity among prepubertal boys. This group of boys is of a different population than the pubertal and post pubertal boys. Therefore we cannot be certain whether the results are more likely due to physiological and metabolic changes during puberty or whether they reflect changes in the environment over time. It would have been ideal if we could have followed up a group of children and adolescents from prepuberty to postpuberty to assess the relationship between pubertal stages and CMRFs. This would require a longitudinal study. However, such study design requires substantial cost and time which would not always be possible to actualize.

We used self-reported methods to assess the pubertal stages, overweight and obesity in our study. Answers from the self-report questionnaire might not always reflect the true health condition. For example, a respondent might report their height/weight incorrectly. Such "self-reported error" could affect the analysis. However, such self-report method has been used in many studies to assess the pubertal stages, overweight and obesity in children/adolescents as stated in previous chapters. The self-report method is relatively inexpensive and data collection is relatively easy. Therefore this method can be used when cost, time and privacy are study considerations. Nevertheless, it is not known whether the size of self-reported errors and biases will vary over time or in different settings.

As we did not give any instructions to the children/adolescents or their parents/guardians for measuring their BW and BH, the sources and methods of obtaining the self-reported values were not known. Within the Hong Kong context of frequent body measures within schools and at the Student Health Service, the term "self-reported" may reflect "school measured" or "Student Health Service measured". This could explain the high level of agreement in SRBW and SRBH. However, the fact that children/adolescents and their families can provide acceptable measures of the BW and BH (however obtained) is of itself important, should such data be required for future large studies, community screening or public education programmes. We suggested that future studies could explore the source of these self-reported values.

CONCLUSION

The results presented in this thesis contribute to the current body of knowledge in the area of childhood overweight/obesity in Hong Kong Chinese children/adolescents. Novel aspects include assessing the performance of Tanner pubertal self-reported questionnaire with Chinese text and Chinese Pubertal Development Scale, self-reported SRDBMI and SRWC for screening overweight and obesity in Hong Kong Chinese children/adolescents. In consideration of a series of health risks related to high BMI and greater WC, SRDBMI and SRWC are valuable screening anthropometric tools to quantify obesity in community settings, possibly for home-assessments and public health/population research. Lastly, the effect of puberty on the prediction of CMRFs provides evidence that future research should consider puberty when assessing children/adolescents with CMRFs clustering. Overall, this thesis provides original views for assessing overweight/obesity using self-reported method in Hong Kong Chinese children/adolescents.

REFERENCES

Addo, O. Y., & Himes, J. H. (2010). Reference curves for triceps and subscapular skinfold thicknesses in US children and adolescents. *Am J Clin Nutr, 91*(3), 635-642. doi: 10.3945/ajcn.2009.28385

Agarwal, S. K., Misra, A., Aggarwal, P., Bardia, A., Goel, R., Vikram, N. K., . . . Pandey, R. M. (2009). Waist circumference measurement by site, posture, respiratory phase, and meal time: implications for methodology. *Obesity (Silver Spring, Md.), 17*(5), 1056-1061.

Alberti, K., Zimmet, P., & Shaw, J. (2006). Metabolic syndrome - a new world-wide definition. A consensus statement from the international diabetes federation. *Diabet Med, 23*, 469-480.

Andersen, L. B., Harro, M., Sardinha, L. B., Froberg, K., Ekelund, U., Brage, S. r., & Anderssen, S. A. (2006). Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *The Lancet, 368*(9532), 299-304.

Arslanian, S. A., & Kalhan, S. C. (1996). Protein turnover during puberty in normal children. *American Journal of Physiology - Endocrinology And Metabolism, 270*(1), E79-E84.

Asayama, K., Oguni, T., Hayashi, K., Dobashi, K., Fukunaga, Y., Kodera, K., . . . Nakazawa, S. (2000). Critical value for the index of body fat distribution based on waist and hip circumferences and stature in obese girls. *Int J Obes Relat Metab Disord., 24*(8), 1026-1031.

Ashwell, M., & Hsieh, S. D. (2005). Six reasons why the waist-to-height ratio is a rapid and effective global indicator for health risks of obesity and how its use could simplify the international public health message on obesity. *International Journal of Food Sciences & Nutrition, 56*(5), 303-307. doi: 10.1080/09637480500195066

Ashwell, M., Lejeune, S., & McPherson, K. (1996). Ratio of waist circumference to height may be better indicator of need for weight management. *BMJ, 312*(7027), 377.

Aslam, M., Eckhauser, A. W., Dorminy, C. A., Dossett, C. M., Choi, L., & Buchowski, M. S. (2009). Assessing body fat changes during moderate weight loss with anthropometry and bioelectrical impedance. *Obesity Research & Clinical Practice, 3*(4), 209-219. doi: DOI: 10.1016/j.orcp.2009.03.005

Azevedo, J. C. V., Brasil, L. M. P., Macedo, T. B. M. A., Pedrosa, L. F. C., & Arrais, R. F. (2009). Comparison between objective assessment and self-assessment of sexual maturation in children and adolescents. *Jornal de pediatria, 85*, 135-142.

Baker, B. L., Birch, L. L., Trost, S. G., & Davison, K. K. (2007). Advanced pubertal status at age 11 and lower physical activity in adolescent girls. *The Journal of pediatrics, 151*(5), 488-493.

Ball, G. D. C., Huang, T. T. K., Gower, B. A., Cruz, M. L., Shaibi, G. Q., Weigensberg, M. J., & Goran, M. I. (2006). Longitudinal changes in insulin sensitivity, insulin secretion, and β-cell function during puberty. *The Journal of Pediatrics, 148*(1), 16-22.

Bell, L. M., Byrne, S., Thompson, A., Ratnam, N., Blair, E., Bulsara, M., . . . Davis, E. A. (2007). Increasing body mass index z-score is continuously associated with complications of overweight in children, even in the healthy weight range. *J Clin Endocrinol Metab, 92*(2), 517-522. doi: 10.1210/jc.2006-1714

Benfield, L. L., Fox, K. R., Peters, D. M., Blake, H., Rogers, I., Grant, C., & Ness, A. (2008). Magnetic resonance imaging of abdominal adiposity in a large cohort of British children. *International Journal of Obesity, 32*, 91-99.

Bigaard, J., Frederiksen, K., Tjonneland, A., Thomsen, B. L., Overvad, K., & Heitmann, B. L. (2005a). Waist circumference and body composition in relation to all-cause mortality in middle-aged men and women. *Int J Obes (Lond), 29*, 778-784. [10.1038/sj.ijo.0802976].

Bigaard, J., Spanggaard, I., Thomsen, B. L., Overvad, K., & Tjonneland, A. (2005). self-reported and technician-measured waist circumferences differ in middle-aged men and women. *Journal of Nutrition, 135*(9), 2263-2270.

Bloch, C. A., Clemons, P., & Sperling, M. A. (1987). Puberty decreases insulin sensitivity. *The Journal of Pediatrics, 110*(3), 481-487.

Bond, L., Clements, J., Bertalli, N., Evans-Whipp, T., McMorris, B. J., Patton, G. C., . . . Catalano, R. F. (2006). A comparison of self-reported puberty using the Pubertal Development Scale and the Sexual Maturation Scale in a school-based epidemiologic survey. *Journal of Adolescence, 29*(5), 709-720.

Boyko, E. J., Fujimoto, W. Y., Leonetti, D. L., & Newell-Morris, L. (2000). Visceral adiposity and risk of type 2 diabetes: a prospective study among Japanese Americans. *Diabetes Care, 23*(4), 465-471. doi: 10.2337/diacare.23.4.465

Brambilla, P., Bedogni, G., Moreno, L. A., Goran, M. I., Gutin, B., Fox, K. R., . . . Pietrobelli, A. (2006). Crossvalidation of anthropometry against magnetic resonance imaging for the assessment of visceral and subcutaneous adipose tissue in children. *Int J Obes Relat Metab Disord, 30*(1), 23-30.

Bray, G. A. (2004). Medical consequences of obesity. *J Clin Endocrinol Metab, 89*, 2583 - 2589.

Bray, G. A., DeLany, J. P., Harsha, D. W., Volaufova, J., & Champagne, C. C. (2001). Evaluation of body fat in fatter and leaner 10-y-old African American and white children: the Baton Rouge Children's Study. *The American Journal of Clinical Nutrition, 73*(4), 687-702.

Bray, G. A., DeLany, J. P., Volaufova, J., Harsha, D. W., & Champagne, C. (2002). Prediction of body fat in 12-y-old African American and white children: evaluation of methods. *The American Journal of Clinical Nutrition, 76*(5), 980-990.

Brener, N. D., McManus, T., Galuska, D. A., Lowry, R., & Wechsler, H. (2003). Reliability and validity of self-reported height and weight among high school students. *Journal of Adolescent Health, 32*(4), 281-287.

Bridges, N. A., Matthews, D. R., Hindmarsh, P. C., & Brook, C. G. (1994). Changes in gonadotrophin secretion during childhood and puberty. *The Journal of endocrinology, 141*(1), 169-176.

Brodie, M. J., Moscrip, V., & Hutcheson, R. (1998). Body composition measurement: a review of hydrodensitometry, anthropometry, and impedance methods. *Nutrition, 14*(3), 296-310.

Brooks-Gunn, J., Warren, M. P., Rosso, J., & Gargiulo, J. (1987). Validity of self-report measures of girls' pubertal status. *Child development,58*(3), 829-841.

Buchholz, A. C., & Bugaresti, J. M. (2005). A review of body mass index and waist circumference as markers of obesity and coronary heart disease risk in persons with chronic spinal cord injury. *Spinal cord : the official journal of the International Medical Society of Paraplegia, 43*(9), 513-518.

Burke, V., Beilin, L. J., Simmer, K., Oddy, W. H., Blake, K. V., Doherty, D., . . . Stanley, F. J. (2004). Predictors of body mass index and associations with cardiovascular risk factors in Australian children: a prospective cohort study. *Int J Obes Relat Metab Disord, 29*(1), 15-23.

Caceres, M., Teran, C., Rodriguez, S., & Medina, M. (2008). Prevalence of insulin resistance and its association with metabolic syndrome criteria among Bolivian children and adolescents with obesity. *BMC Pediatrics, 8*(1), 31.

Calle, E. E., Thun, M. J., Petrelli, J. M., Rodriguez, C., & Heath, C. W. (1999). Body-mass index and mortality in a prospective cohort of U.S. adults. *New England Journal of Medicine, 341*(15), 1097-1105. doi:10.1056/NEJM199910073411501

Campagnolo, P. D. B., Hoffman, D. J., & Vitolo, M. R. (2010). Waist-to-height ratio as a screening tool for children with risk factors for cardiovascular disease. *Annals of Human Biology, 0*(0), null. doi: doi:10.3109/03014460.2010.526147

Caprio, S., Bronson, M., Sherwin, R. S., Rife, F., & Tamborlane, W. V. (1996). Co-existence of severe insulin resistance and hyperinsulinaemia in pre-adolescent obese children. *Diabetologia, 39*(12), 1489-1497.

Carskadon, M. A., & Acebo, C. (1993). A self-administered rating scale for pubertal development. *Journal of Adolescent Health, 14*(3), 190-195.

Carter, P. J., Taylor, B. J., Williams, S. M., & Taylor, R. W. (2011). Longitudinal analysis of sleep in relation to BMI and body fat in children: the FLAME study. *BMJ, 342*. doi: 10.1136/bmj.d2712

Chan, N., Sung, R., Kong, A., Goggins, W., So, H., & Nelson, E. (2008). Reliability of pubertal self-assessment in Hong Kong Chinese children. *J Paediatr Child Health, 44*(6), 353 - 358.

Chan, N. P., Sung, R. Y., Nelson, E. A., So, H. K., Tse, Y. K., & Kong, A. P. (2010). Measurement of pubertal status with a Chinese self-report pubertal development scale. *Matern Child Health J 14*, 466–473. doi: DOI 10.1007/s10995-009-0481-2

Chen, M. M., Lear, S. A., Gao, M., Frohlich, J. J., & Birmingham, C. L. (2001). Intraobserver and interobserver reliability of waist circumference and the waist-to-hip ratio. *Obesity, 9*(10), 651.

Chen, X., & Wang, Y. (2008). Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. *Circulation, 117*(25), 3171-3180. doi: 10.1161/circulationaha.107.730366

Chen, X., & Wang, Y. (2009). The influence of sexual maturation on blood pressure and body fatness in African-American adolescent girls and boys. *American Journal of Human Biology, 21*(1), 105-112. doi: 10.1002/ajhb.20832

Cheng, T. O. (2004). Waist circumference versus body mass index in risk prediction of coronary heart disease: comparing apples and oranges. *Journal of internal medicine, 255*(6), 690-691. doi: 10.1111/j.1365-2796.2004.01329.x

Cheng, T. O. (2009). Central obesity is a more sensitive predictor of cardiovascular disease than body mass index in the Chinese population. *International journal of cardiology, 135*(3), 385-385.

Cheung, P. C. H., Ip, P. L. S., Lam, S. T., & Bibby, H. (2007). A study on body weight perception and weight control behaviours among adolescents in Hong Kong. *Hong Kong Med J 13*, 16-21.

Chiarelli, F., & Marcovecchio, M. L. (2008). Insulin resistance and obesity in childhood. *Eur J Endocrinol, 159*(suppl_1), S67-74. doi: 10.1530/eje-08-0245

Chumlea, W. C., Guo, S. S., Kuczmarski, R. J., Flegal, K. M., Johnson, C. L., Heymsfield, S. B., . . . Hubbard, V. S. (2002). Body composition estimates from

NHANES III bioelectrical impedance data. *Int J Obes Relat Metab Disord, 26*(12), 1596-1609.

Cohen, J. (1968). Weighted kappa: nominal scale agreement provision for scaled disagreement or partial credit. *Psychological bulletin, 70*(4), 213-220.

Cole, T. J., Bellizzi, M. C., Flegal, K. M., & Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ, 320*(7244), 1240. doi: 10.1136/bmj.320.7244.1240

Committee on Nutrition. (2003). Prevention of Pediatric Overweight and Obesity. *Pediatrics, 112*(2), 424-430.

Cook, S., Weitzman, M., Auinger, P., Nguyen, M., & Dietz, W. H. (2003). Prevalence of a metabolic syndrome phenotype in adolescents: findings from the Third National Health and Nutrition Examination Survey, 1988-1994. *Arch Pediatr Adolesc Med, 157*, 821-827.

Cruz, M. L., Weigensberg, M. J., Huang, T. T.-K., Ball, G., Shaibi, G. Q., & Goran, M. I. (2004). The metabolic syndrome in overweight Hispanic Youth and the role of insulin sensitivity. *J Clin Endocrinol Metab, 89*(1), 108-113. doi: 10.1210/jc.2003-031188

Dalton, M., Cameron, A. J., Zimmet, P. Z., Shaw, J. E., Jolley, D., Dunstan, D. W., . . . (2003). Waist circumference, waist–hip ratio and body mass index and their correlation with cardiovascular disease risk factors in Australian adults. *Journal of internal medicine, 254*(6), 555-563. doi: 10.1111/j.1365-2796.2003.01229.x

Daniels, S. R., Khoury, P. R., & Morrison, J. A. (2000). Utility of different measures of body fat distribution in children and adolescents. *American Journal of Epidemiology, 152*(12), 1179-1184.

Daniels, S. R., Obarzanek, E., Barton, B. A., Kimm, S. Y. S., Similo, S. L., & Morrison, J. A. (1996). Sexual maturation and racial differences in blood pressure in girls: The National Heart, Lung, and Blood Institute Growth and Health Study. *The Journal of Pediatrics, 129*(2), 208-213.

Danubio, M. E., Miranda, G., Vinciguerra, M. G., Vecchi, E., & Rufo, F. (2008). Comparison of self-reported and measured height and weight: Implications for obesity research among young adults. *Economics & Human Biology, 6*(1), 181-190.

Davison, K. K., Werder, J. L., Trost, S. G., Baker, B. L., & Birch, L. L. (2007). Why are early maturing girls less active? Links between pubertal development, psychological well-being, and physical activity among girls at ages 11 and 13. *Social Science & Medicine, 64*(12), 2391-2404.

de Koning, L., Merchant, A. T., Pogue, J., & Anand, S. S. (2007). Waist circumference and waist-to-hip ratio as predictors of cardiovascular events: meta-regression analysis of prospective studies. *European Heart Journal, 28*(7), 850-856. doi: 10.1093/eurheartj/ehm026

De Simone, M., Verrotti, A., & Iughetti, L. (2001). Increased visceral adipose tissue is associated with increased circulating insulin and decreased sex hormone binding globulin levels in massively obese adolescent girls. *J Endocrinol Invest, 24*, 438-444.

Dekkers, J. C., van Wier, M. F., Hendriksen, I. J., Twisk, J. W., & van Mechelen, W. (2008). Accuracy of self-reported body weight, height and waist circumference in a Dutch overweight working population. *BMC medical research methodology, 8*(1), 69.

DeLong, E. R., DeLong, D. M., & Clarke-Pearson, D. L. (1988). Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics, 44*(3), 837-845.

Denzer, C., Weibel, A., Muche, R., Karges, B., Sorgo, W., & Wabitsch, M. (2007). Pubertal development in obese children and adolescents. *Int J Obes, 31*(10), 1509-1519.

Desmangles, J. C., Lappe, J. M., Lipaczewski, G., & Haynatzki, G. (2006). Accuracy of pubertal Tanner staging self-reporting. *Journal of pediatric endocrinology & metabolism : JPEM, 19*(3), 213-221.

Despres, J., Moorjani, S., Lupien, P., Tremblay, A., Nadeau, A., & Bouchard, C. (1990). Regional distribution of body fat, plasma lipoproteins, and cardiovascular disease. *Arterioscler Thromb Vasc Biol, 10*(4), 497-511.

Despres, J. P. (2007). Cardiovascular disease under the influence of excess visceral fat. *Crit Pathw Cardiol, 6*(Journal Article), 51-59.

Dorn, L. D., & Biro, F. M. (2011). Puberty and its measurement: a decade in review. *Journal of Research on Adolescence, 21*(1), 180-195. doi: 10.1111/j.1532-7795.2010.00722.x

Duke, P. M., Litt, I. F., & Gross, R. T. (1980). Adolescents' self-assessment of sexual maturation. *Pediatrics, 66*(6), 918-920.

Ebbeling, C. B., Pawlak, D. B., & Ludwig, D. S. (2002). Childhood obesity: public-health crisis, common sense cure.. *Lancet, 360*, 473-482. doi: 10.1016/S0140-6736(02)09678-2

Eisenmann, J. C. (2005). Waist circumference percentiles for 7- to 15-year-old Australian children. *Acta Paediatrica, 94*(9), 1182-1185.

Elgar, F. J., Roberts, C., Tudor-Smith, C., & Moore, L. (2005). Validity of self-reported height and weight and predictors of bias in adolescents. *Journal of Adolescent Health, 37*(5), 371-375.

Elgar, F. J., & Stewart, J. M. (2008). Validity of self-report screening for overweight and obesity. Evidence from the Canadian Community Health Survey. *Canadian journal of public health.Revue canadienne de sante publique, 99*(5), 423-427.

Ellis, B. J. (2004). Timing of pubertal maturation in girls: an integrated life history approach. *Psychological bulletin, 130*(6), 920-958.

Esmaillzadeh, A., Mirmiran, P., & Azizi, F. (2006). Clustering of metabolic abnormalities in adolescents with the hypertriglyceridemic waist phenotype. *The American Journal of Clinical Nutrition, 83*(1), 36-46.

Fang, J., Zhang, J. P., Luo, C. X., Yu, X. M., & Lv, L. Q. (2010). Carotid Intima-media thickness in childhood and adolescent obesity relations to abdominal obesity, high triglyceride level and insulin resistance. *Int J Med Sci., 18*(7), 278-283.

Fernandez, J. R., Redden, D. T., Pietrobelli, A., & Allison, D. B. (2004). Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. *Journal of Pediatrics, 145*, 427-430.

Flegal, K. M. (1993). Defining obesity in children and adolescents: epidemiologic approaches. *Crit Rev Food Sci Nutr., 33*(4-5), 307-312.

Flegal, K. M., Ogden, C. L., Wei, R., Kuczmarski, R. L., & Johnson, C. L. (2001). Prevalence of overweight in US children: comparison of US growth charts from the Centers for Disease Control and Prevention with other reference values for body mass index. *The American Journal of Clinical Nutrition, 73*(6), 1086-1093.

Fleiss, J. L. (1981). *Statistical methods for rates and proportions* (Vol. 2nd). New York: Wiley.

Fleiss, J. L., & Cohen, J. (1973). The equivalence of weighted kappa and the intraclass correlation coefficient as measures of reliability. *Educational and Psychological Measurement, 33*(3), 613-619.

Fleiss, J. L., Levin, B. A., & Paik, M. C. (2003). *Statistical methods for rates and proportions* (Vol. 3rd). Hoboken, N.J.: Wiley-Interscience.

Fonseca, H., Silva, A. M., Matos, M. G., Esteves, I., Costa, P., Guerra, A., & Gomes-Pedro, J. (2010). Validity of BMI based on self-reported weight and height in adolescents. *Acta Paediatrica (Oslo, Norway : 1992), 99*(1), 83-88.

Folsom, A. R., Kushi, L. H., Anderson, K. E., Mink, P. J., Olson, J. E., Hong, C.-P., . . . Prineas, R. J. (2000). Associations of general and abdominal obesity with multiple health outcomes in older women: The Iowa Women's Health Study. *Arch Intern Med, 160*(14), 2117-2128. doi: 10.1001/archinte.160.14.2117

Ford, E. S. (2005). Prevalence of the metabolic syndrome defined by the International Diabetes Federation among adults in the U.S. *Diabetes care, 28*, 2745-2749.

Fox, C. S., Massaro, J. M., & Hoffmann, U. (2007). Abdominal visceral and subcutaneous adipose tissue compartments: association with metabolic risk factors in the Framingham Heart Study. *Circulation, 116*, 39-48. doi: 10.1161/CIRCULATIONAHA.106.675355

Freedman, D., Pisani, R., & Purves, R. (1998). *Statistics* (3rd. ed.). New York: W.W. Norton.

Freedman, D. S., Fulton, J. E., Dietz, W. H., Pan, L., Nihiser, A. J., Srinivasan, S. R., & Berenson, G. S. (2010). The identification of children with adverse risk factor levels by body mass index cutoffs from 2 classification systems: the Bogalusa Heart Study. *The American Journal of Clinical Nutrition, 92*(6), 1298-1305. doi: 10.3945/ajcn.2010.29758

Freedman, D. S., & Sherry, B. (2009). The Validity of BMI as an indicator of body fatness and risk among children. *Pediatrics, 124*(Supplement_1), S23-34.

Freedman, D. S., Kahn, H. S., Mei, Z., Grummer-Strawn, L. M., Dietz, W. H., Srinivasan, S. R., & Berenson, G. S. (2007). Relation of body mass index and waist-to-height ratio to cardiovascular disease risk factors in children and adolescents: the Bogalusa Heart Study. *American Journal of Clinical Nutrition, 86*(1), 33-40.

Freedman, D. S., Khan, L. K., Dietz, W. H., Srinivasan, S. R., & Berenson, G. S. (2001). Relationship of childhood obesity to coronary heart disease risk factors in adulthood: the Bogalusa Heart Study. *Pediatrics, 108*(3), 712-718. doi: 10.1542/peds.108.3.712

Gharib, N., & Rasheed, P. (2009). Anthropometry and body composition of school children in Bahrain. *Ann Saudi Med., 29*(4): 258–269. doi: 10.4103/0256-4947.55309

Gil-Campos, M., Cañete, R., & Gil, A. (2004). Adiponectin, the missing link in insulin resistance and obesity. *Clinical Nutrition, 23*(5), 963-974. doi: 10.1016/j.clnu.2004.04.010

Golley, R. K., Magarey, A. M., Steinbeck, K. S., Baur, L. A., & Daniels, L. A. (2006). Comparison of metabolic syndrome prevalence using six different definitions in overweight pre-pubertal children enrolled in a weight management study. *Int J Obes, 30*(5), 853-860.

Goodman, E., & Strauss, R. S. (2003). Self-reported height and weight and the definition of obesity in epidemiological studies. *Journal of Adolescent Health, 33*(3), 140-141.

Goran, M. I., & Gower, B. A. (2001). Longitudinal Study on Pubertal Insulin Resistance. *Diabetes, 50*(11), 2444-2450.

Graber, J. A., Lewinsohn, P. M., Seeley, J. R., & Brooks-Gunn, J. (1997). Is psychopathology associated with the timing of pubertal development? *Journal of the American Academy of Child and Adolescent Psychiatry, 36*(12), 1768-1776.

Graber, J. A., Seeley, J. R., Brooks-Gunn, J., & Lewinsohn, P. M. (2004). Is pubertal timing associated with psychopathology in young adulthood. *Journal of the American Academy of Child and Adolescent Psychiatry, 43*(6), 718-726.

Griggs, R. C., Kingston, W., Jozefowicz, R. F., Herr, B. E., Forbes, G., & Halliday, D. (1989). Effect of testosterone on muscle mass and muscle protein synthesis. *Journal of Applied Physiology, 66*(1), 498-503.

Guo, S. S., Huang, C., Maynard, L. M., Demerath, E., Towne, B., Chumlea, W. C., & Siervogel, R. M. (2000). Body mass index during childhood, adolescence and young adulthood in relation to adult overweight and adiposity: the Fels Longitudinal Study. *Int J Obes, 24,* 1628-1635. doi: 10.1038/sj.ijo.0801461

Guo, S. S., Wu, W., Chumlea, W. C., & Roche, A. F. (2002). Predicting overweight and obesity in adulthood from body mass index values in childhood and adolescence. *The American Journal of Clinical Nutrition, 76*(3), 653-658.

Gupta, D. K., Shah, P., Misra, A., Bharadwaj, S., Gulati, S., Gupta, N., . . . Goel, K. (2011). Secular Trends in Prevalence of Overweight and Obesity from 2006 to 2009 in Urban Asian Indian Adolescents Aged 14-17 Years. *PLoS One, 6*(2), e17221. . doi: 10.1371/journal.pone.0017221.

Han, J. C., Lawlor, D. A., & Kimm, S. Y. S. (2010). Childhood obesity. *The Lancet, 375*(9727), 1737-1748. doi: Doi: 10.1016/s0140-6736(10)60171-7

Hara, M. S., E; Iwata, F; Okada, T; Harada, K. (2002). Waist-to-height ratio is the best predictor of cardiovascular disease risk factors in Japanese schoolchildren. *J Atheroscler Thromb, 9*(3), 127-132.

Hayward, C., Killen, J. D., Wilson, D. M., Hammer, L. D., Litt, I. F., Kraemer, H. C., . . . Taylor, C. B. (1997). Psychiatric risk associated with early puberty in adolescent girls. *Journal of the American Academy of Child and Adolescent Psychiatry, 36*(2), 255-262.

Hergenroeder, A. C., Hill, R. B., Wong, W. W., Sangi-Haghpeykar, H., & Taylor, W. (1999). Validity of self-assessment of pubertal maturation in African American and European American adolescents. *Journal of Adolescent Health, 24*(3), 201-205.

Himes, J. H. (1999). Maturation-related deviations and misclassification of stature and weight in adolescence. *American Journal of Human Biology, 11*(4), 499-504. doi: 10.1002/(sici)1520-6300(1999)11:4<499::aid-ajhb9>3.0.co;2-m

Himes, J. H., & Faricy, A. (2001). Validity and reliability of self-reported stature and weight of US adolescents. *American Journal of Human Biology : The Official Journal of the Human Biology Council, 13*(2), 255-260.

Himes, J. H., Hannan, P., Wall, M., & Neumark-Sztainer, D. (2005). Factors associated with errors in self-reports of stature, weight, and body mass index in Minnesota adolescents. *Annals of Epidemiology, 15*(4), 272-278.

Hirsch, M., Lunenfeld, B., Modan, M., Ovadia, J., & Shemesh, J. (1985). Spermarche--the age of onset of sperm emission. *Journal of Adolescent Health Care : official publication of the Society for Adolescent Medicine, 6*(1), 35-39.

Hirschler, Valeria, A., Claudio de Lujan, C., Maria, M., Gustavo, J., & Mauricio. (2005). Can waist circumference Identify children with the metabolic syndrome? *Archives of Pediatrics & Adolescent Medicine, 159*(8), 740-744.

Ho, S. Y., Lam, T. H., & Janus, E. D. (2003). Waist to stature ratio is more strongly associated with cardiovascular risk factors than other simple anthropometric indices. *Annals of Epidemiology, 13*(10), 683-691.

Hoffer, F. A. (2005). Magnetic resonance imaging of abdominal masses in the pediatric patient. *Semin Ultrasound CT MR., 26*(4), 212-223.

Holst-Schumacher, I. N.-R., H., Monge-Rojas, R., & Barrantes-Santamaría, M. (2009). Components of the metabolic syndrome among a sample of overweight and obese Costa Rican schoolchildren. *Food Nutr Bull., 30*(2), 161-170.

Hosmer, D. W., & Lemeshow, S. (2000). *Applied Logistic Regression*. New York: Wiley.

Hsieh, S. D., Yoshinaga, H., & Muto, T. (2003). 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., 27*(5), 610-616.

Huang, K. C., Lee, M. S., Lee, S. D., Chang, Y. H., Lin, Y. C., Tu, S. H., & Pan, W. H. (2005). Obesity in the elderly and its relationship with cardiovascular risk factors in Taiwan. *Obes Res., 13*(1), 170-178.

Jackson, A., Stanforth, P., Gagnon, J., Rankinen, T., Leon, A., Rao, D., . . . Wilmore, J. (2002). The effect of sex, age and race on estimating percentage body fat from body mass index: the Heritage Family Study. *Int J Obes Relat Metab Disord, 26*, 789 - 796.

Janssen, I., Katzmarzyk, P. T., Srinivasan, S. R., Chen, W., Malina, R. M., Bouchard, C., & Berenson, G. S. (2005). Utility of childhood BMI in the prediction of adulthood disease: comparison of national and international references. *Obesity research, 13*(6), 1106-1115.

Ji, C. Y. (2001). Age at spermarche and comparison of growth and performance of pre- and post-spermarcheal Chinese boys. *American Journal of Human Biology : The Official Journal of the Human Biology Council, 13*(1), 35-43.

Kahn, H. S. (2006). The lipid accumulation product is better than bmi for identifying diabetes: a population-based comparison. *Diabetes Care, 29*(1), 151-153.

Kahn, H. S., Imperatore, G., & Cheng, Y. J. (2005). A population-based comparison of BMI percentiles and waist-to-height ratio for identifying cardiovascular risk in youth. *The Journal of Pediatrics, 146*(4), 482-488.

Kahn, S. E. (2001). The importance of β cell failure in the development and progression of type 2 diabetes. *J Clin Endocrinol Metab, 86*(9), 4047-4058. doi: 10.1210/jc.86.9.4047

Kannel, W. B., Cupples, L. A., Ramaswami, R., Stokes, J. r., Kreger, B. E., & Higgins, M. (1991). Regional obesity and risk of cardiovascular disease; the Framingham Study. *J Clin Epidemiol., 44*(2), 183-190.

Karnehed, N., Rasmussen, F., & Kark, M. (2007). Obesity in young adulthood and later disability pension: a population-based cohort study of 366,929 Swedish men. *Scand J Public Health, 35*, 48-54.

Katon, J. G., Flores, Y. N., & Salmerón, J. (2009). Sexual maturation and metabolic profile among adolescents and children of the Health Worker Cohort Study in Mexico. *Salud Publica de Mexico, 51*, 219-226.

Katzmarzyk, P., Craig, C., & Gauvin, L. (2007). Adiposity, physical fitness and incident diabetes: the physical activity longitudinal study. *Diabetologia, 50*(3), 538-544. doi: 10.1007/s00125-006-0554-3

Katzmarzyk, P. T. (2004). Waist circumference percentiles for Canadian youth 11-18 y of age. *Eur J Clin Nutr, 58*(Journal Article), 1011-1015.

Katzmarzyk, P. T., Pérusse, L., Malina, R. M., Bergeron, J., Després, J.-P., & Bouchard, C. (2001). Stability of indicators of the metabolic syndrome from childhood and adolescence to young adulthood: the Québec Family Study. *Journal of Clinical Epidemiology, 54*(2), 190-195. doi: Doi: 10.1016/s0895-4356(00)00315-2

Katzmarzyk, P. T., Tremblay, A., Pérusse, L., Després, J.-P., & Bouchard, C. (2003). The utility of the international child and adolescent overweight guidelines for predicting coronary heart disease risk factors. *Journal of Clinical Epidemiology, 56*(5), 456-462. doi: Doi: 10.1016/s0895-4356(02)00595-4

Kelishadi, R., Gheiratmand, R., Ardalan, G., Adeli, K., Mehdi Gouya, M., Mohammad Razaghi, E., . . . Mehdi Riazi, M. (2007). Association of anthropometric indices with cardiovascular disease risk factors among children and adolescents: CASPIAN Study. *International Journal of Cardiology, 117*(3), 340-348. doi: DOI: 10.1016/j.ijcard.2006.06.012

Kipping, R. R., Jago, R., & Lawlor, D. A. (2008). Obesity in children. Part 1: epidemiology, measurement, risk factors, and screening. *BMJ, 337*. doi: 10.1136/bmj.a1824

Klein, D. J., Aronson Friedman, L., Harlan, W. R., Barton, B. A., Schreiber, G. B., Cohen, R. M., . . . Morrison, J. A. (2004). Obesity and the development of insulin resistance and impaired fasting glucose in black and white adolescent girls: a longitudinal study. *Diabetes Care, 27*(2), 378-383.

Klein, S., Allison, D. B., Heymsfield, S. B., Kelley, D. E., Leibel, R. L., Nonas, C., & Kahn, R. (2007). Waist circumference and cardiometabolic risk: a consensus statement from shaping America's health: Association for Weight Management and Obesity Prevention; NAASO, The Obesity Society; the American Society for Nutrition; and the American Diabetes Association. *Diabetes Care, 30*(6), 1647-1652.

Ko, G. T., Chan, J. C., Cockram, C. S., & Woo, J. (1999). Prediction of hypertension, diabetes, dyslipidaemia or albuminuria using simple anthropometric indexes in Hong Kong Chinese. [10.1038/sj.ijo.0801043]. *Int J Obes Relat Metab Disord, 23*, 1136-1142.

Kong, A., Choi, K.-C., Ho, C., Chan, M., Wong, C., Liu, E., . . . Chan, J. (2011). Hong Kong Chinese school children with elevated urine melamine levels: a prospective follow up study. *BMC Public Health, 11*(1), 354.

Kong, A., Choi, K.-C., Li, A., Hui, S., Chan, M., Wing, Y., . . . Chan, J. (2010). Association between physical activity and cardiovascular risk in chinese youth independent of age and pubertal stage. *BMC Public Health, 10*(1), 303.

Kong, A. P., Wing, Y.-K., Choi, K. C., Li, A. M., Ko, G. T. C., Ma, R. C., . . . Chan, J. C. Associations of sleep duration with obesity and serum lipid profile in children and adolescents. *Sleep medicine, In Press, Corrected Proof*. doi: 10.1016/j.sleep.2010.12.015

Kubo, T. S., K; Mimura, Y; Furujo, M; Shiraga, H; Kanadani, T; Koyama, T; Shimizu, J; Kimura, T; Ogura, K; Mori, S. (2010). Evaluation of partial body composition using bioelectrical impedance in Japanese children. *Asia Pac J Clin Nutr, 19*(4), 594-601.

Kyle, U. G., Bosaeus, I., De Lorenzo, A. D., Deurenberg, P., Elia, M., Gómez, J. M., . . . Pichard, C. (2004a). Bioelectrical impedance analysis--part I: review of principles and methods. *Clinical Nutrition, 23*(5), 1226-1243. doi: DOI: 10.1016/j.clnu.2004.06.004

Kyle, U. G., Bosaeus, I., De Lorenzo, A. D., Deurenberg, P., Elia, M., Manuel Gómez, J., . . . Pichard, C. (2004b). Bioelectrical impedance analysis--part II: utilization in clinical practice. *Clinical Nutrition, 23*(6), 1430-1453. doi: DOI: 10.1016/j.clnu.2004.09.012

Lam, T. H., Shi, H. J., Ho, L. M., Stewart, S. M., & Fan, S. (2002). Timing of pubertal maturation and heterosexual behavior among Hong Kong Chinese adolescents. *Archives of Sexual Behavior, 31*(4), 359-366.

Lamb, M. M., Beers, L., Reed-Gillette, D., & McDowell, M. A. (2011). Feasibility of an audio computer-assisted self-interview method to self-assess sexual maturation. *The Journal of Adolescent Health : official publication of the Society for Adolescent Medicine, 48*(4), 325-330.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*(1), 159-174.

Larsen, J. K., Ouwens, M., Engels, R. C. M. E., Eisinga, R., & Van Strien, T. (2008). Validity of self-reported weight and height and predictors of weight bias in female college students. *Appetite, 50*(2-3), 386-389.

Lazzer, S., Boirie, Y., Meyer, M., & Vermorel, M. (2003). Evaluation of two foot-to-foot bioelectrical impedance analysers to assess body composition in overweight and obese adolescents. *Br J Nutr., 90*(5), 987-992.

Lear, S. A. (2005). Waist circumference is simpler than body mass index. *Clinical Chemistry, 51*(6), 1082-1084.

Lear, S. A., James, P. T., Ko, G. T., & Kumanyika, S. (2009). Appropriateness of waist circumference and waist-to-hip ratio cutoffs for different ethnic groups. *Eur J Clin Nutr, 64*(1), 42-61.

Leccia, G., Marotta, T., Masella, M. R., Mottola, G., Mitrano, G., Golia, F., . . . Ferrara, L. A. (1999). Sex-related influence of body size and sexual maturation on blood pressure in adolescents. *Eur J Clin Nutr, 53*(4), 333-337.

Lee, K., Valeria, B., Kochman, C., & Lenders, C. M. (2006). Self-assessment of height, weight, and sexual maturation: validity in overweight children and adolescents. *Journal of Adolescent Health, 39*(3), 346-352.

Lee, M. M. C., Chang, K. S. F., & Chan, M. M. C. (1963). Sexual maturation of chinese girls in Hong Kong. *Pediatrics, 32*(3), 389-398.

Lee, S. J., Bacha, F., Gungor, N., & Arslanian, S. A. (2006). Waist circumference is an independent predictor of insulin resistance in black and white youths. *The Journal of Pediatrics, 148*(2), 188-194.

Lee, S. Y., & Gallagher, D. (2008). Assessment methods in human body composition. *Curr Opin Clin Nutr Metab Care, 11*(5), 566-572.

Leung, S., Lau, J., Xu, Y., Tse, L., Huen, K., Wong, G., . . . Yeung, W. (1996). Secular changes in standing height, sitting height and sexual maturation of Chinese-the Hong Kong Growth Study, 1993. *Ann Hum Biol, 23*, 297-306.

Li, C., Ford, E. S., Mokdad, A. H., & Cook, S. (2006). Recent trends in waist circumference and waist-height ratio among US children and adolescents. *Pediatrics, 118*(5 (Electronic)), e1390-1398.

Li, C., Huang, T.-K., Cruz, M. L., & Goran, M. I. (2006). Birth weight, puberty, and systolic blood pressure in children and adolescents: a longitudinal analysis. *J Hum Hypertens, 20*(6), 444-450.

Li, Y., Graubard, B. I., & Korn, E. L. (2010). Application of nonparametric quantile regression to body mass index percentile curves from survey data. *Statistics in medicine, 29*(5), 558-572.

Liu, A., Hills, A. P., Hu, X., Li, Y., Du, L., Xu, Y. Y., . . . Ma, G. (2010). Waist circumference cut-off values for the prediction of cardiovascular risk factors clustering in Chinese school-aged children: a cross-sectional study. *BMC Public Health, 10*(1), 82.

Loftin, M. N., J; Going, S; Sothern, M; Schmitz, KH; Ring, K; Tuuri, G; Stevens, J. (2007). Comparison of the validity of anthropometric and bioelectric impedance equations to assess body composition in adolescent girls. *Int J Body Compos Res, 5*(1), 1-8.

Lohman, T. C., B; Himes, JH; Davis, CE; Stewart, D; Houtkooper, L; Going, SB; Hunsberger, S; Weber, JL; Reid, R; Stephenson, L. (2000). Estimation of body fat from anthropometry and bioelectrical impedance in Native American children. *Int J Obes Relat Metab Disord, 24*(8), 982-988.

Maffeis, C., Corciulo, N., Livieri, C., Rabbone, I., Trifiro, G., Falorni, A., . . . Grezzani, A. (2003). Waist circumference as a predictor of cardiovascular and metabolic risk factors in obese girls. *Eur J Clin Nutr, 57*(4), 566-572.

Maffeis, C., Pietrobelli, A., Grezzani, A., Provera, S., & Tatò, L. (2001). Waist circumference and cardiovascular risk factors in prepubertal children. *Obes Res., 9*(3), 179-187.

Mahan, L. K., & Escott-Stump, S. (1996). *Krause's food, nutrition, and diet therapy* (9th ed.). Philadelphia: WB Saunders.

Marshall, W. A., & Tanner, J. M. (1968). Growth and physiological development during adolescence. *Annual Review of Medicine, 19*, 283-300.

Marshall, W. A., & Tanner, J. M. (1969). Variations in pattern of pubertal changes in girls. *Arch Dis Child, 44*, 291-303.

Matsuzawa, Y., Nakamura, T., Shimomura, I., & Kotani, K. (1995). Visceral fat accumulation and cardiovascular disease. *Obes Res, 3 Suppl 5*, 645S-647S.

Matthaei, S., Stumvoll, M., Kellerer, M., & Haring, H.-U. (2000). Pathophysiology and Pharmacological Treatment of Insulin Resistance. *Endocr Rev, 21*(6), 585-618. doi: 10.1210/er.21.6.585

Maynard, L. M., Wisemandle, W., Roche, A. F., Chumlea, W. C., Guo, S. S., & Siervogel, R. M. (2001). Childhood Body Composition in Relation to Body Mass Index. *Pediatrics, 107*(2), 344-350. doi: 10.1542/peds.107.2.344

McCarthy, H., Jarrett, H., & Crawley, H. (2001). The development of waist circumference percentiles in British children aged 5.0-16.9 y. *Eur J Clin Nutr, 55*(Journal Article), 902-907.

McCarthy, H. D., & Ashwell, M. (2006). A study of central fatness using waist-to-height ratios in UK children and adolescents over two decades supports the simple message - `keep your waist circumference to less than half your height'. *Int J Obes, 30*(6), 988-992.

McCarthy, H. D., Cole, T. J., Fry, T., Jebb, S. A., & Prentice, A. M. (2006). Body fat reference curves for children. *Int J Obes, 30*(4), 598-602.

McCarthy, H. D., Ellis, S. M., & Cole, T. J. (2003). Central overweight and obesity in British youth aged 11-16 years: cross sectional surveys of waist circumference. *BMJ, 326*(7390), 624.

Messiah, S. E., Arheart, K. L. E., Lipshultz, S. E., & Miller, T. L. (2008). Body Mass Index, Waist circumference, and cardiovascular risk factors in adolescents. *Journal of Pediatrics, 153*(6), 845-850e841.

Misra, A., & Vikram, N. K. (2003). Clinical and pathophysiological consequences of abdominal adiposity and abdominal adipose tissue depots. *Nutrition, 19*(5), 457-466. doi: Doi: 10.1016/s0899-9007(02)01003-1

Moller, D. E., & Flier, J. S. (1991). Insulin Resistance - Mechanisms, Syndromes, and Implications. *New England Journal of Medicine, 325*(13), 938-948. doi: doi:10.1056/NEJM199109263251307

Montague, C. T., & O'Rahilly, S. (2000). The perils of portliness: causes and consequences of visceral adiposity. *Diabetes, 49*, 883-888. doi: 10.2337/diabetes.49.6.883

Moran, A., Jacobs, D. R., Steinberger, J., Hong, C. P., Prineas, R., Luepker, R., & Sinaiko, A. R. (1999). Insulin resistance during puberty: results from clamp studies in 357 children. *Diabetes, 48*(10), 2039-2044.

Moran, A., Jacobs, D. R. J., Steinberger, J., Cohen, P., Hong, C.P., Prineas, R., & Sinaiko, A. R. (2002). Association between the insulin resistance of puberty and the insulin-like growth factor-I/growth hormone axis. *Journal of Clinical Endocrinology Metabolism, 87*(10), 4817-4820.

Moreno, L. A., Pineda, I., Rodriguez, G., Fleta, J., Sarria, A., & Bueno, M. (2002). Waist circumference for the screening of the metabolic syndrome in children. *Acta Pædiatrica, 91*(12), 1307-1312. doi: 10.1111/j.1651-2227.2002.tb02825.x

Moreno, L. A., Sarría, A., Fleta, J., Rodríguez, G., & Bueno, M. (2000). Trends in body mass index and overweight prevalence among children and adolescents in the region of Aragón (Spain) from 1985 to 1995. *Int J Obes Relat Metab Disord, 24*(7), 925-931.

Morris, N. M., & Udry, J. R. (1980). Validation of a self-administered instrument to assess stage of adolescent development. *J Youth Adolesc, 9*(3), 271-280.

Mueller, W. H., Harris, R. B., & Labather, D. R. (2004). Percentiles of body composition from bioelectrical impedance and body measurements in US adolescents 8-17 years old: Project Heartbeat! *Am J Human Biol, 16*, 135-150. doi:10.1002/ajhb.20002

National Heart Lung and Blood Institute. (1998). Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. *Obes Res, 6*(Suppl. 2), 51S-209S.

National Institutes of Health. (2000). *The practical guide to the identification,evaluation and treatment of overweight and obesity in adults*. MD: Bethesda.

National Institutes of Health. (2011). Obesity/overweight Retrieved 7th June 2011, 2011, from http://www.nichd.nih.gov/health/topics/Obesity.cfm

Neinstein, L. S. (1982). Adolescent self-assessment of sexual maturation: reassessment and evaluation in a mixed ethnic urban population. *Clinical pediatrics, 21*(8), 482-484.

Ng, V. W. S., Kong, A. P. S., Choi, K., Ozaki, R., Wong, G. W. K., So, W. Y., . . . Chan, J. C. N. (2007). BMI and waist circumference in predicting cardiovascular risk factor clustering in Chinese adolescents. *Obesity, 15*(2), 494-503.

Norris, S. A., & Richter, L. M. (2005). Usefulness and reliability of Tanner pubertal self-rating to urban black adolescents in South Africa. *Journal of Research on Adolescence, 15*(4), 609-624.

Norris, S. A., & Richter, L. M. (2008). Are there short cuts to pubertal assessments? self-reported and assessed group differences in pubertal development in African adolescents. *Journal of Adolescent Health, 42*(3), 259-265.

Nottelmann, E. D., Susman, E. J., Dorn, L. D., Inoff-Germain, G., Loriaux, D. L., Cutler, G. B., Jr., & Chrousos, G. P. (1987). Developmental processes in early adolescence. Relations among chronologic age, pubertal stage, height, weight, and serum levels of gonadotropins, sex steroids, and adrenal androgens. *Journal of Adolescent Health Care : official publication of the Society for Adolescent Medicine, 8*(3), 246-260.

Ochiai, H., Shirasawa, T., Nishimura, R., Morimoto, A., Shimada, N., Ohtsu, T., . . . Kokaze, A. (2010). Relationship of body mass index to percent body fat and waist circumference among schoolchildren in Japan - the influence of gender and obesity: a population-based cross-sectional study. *BMC Public Health, 10*(1), 493.

Ogden, C. L., Carroll, M. D., Curtin, L. R., Lamb, M. M., & Flegal, K. M. (2010). Prevalence of high body mass index in US children and adolescents, 2007-2008. *JAMA: The Journal of the American Medical Association, 303*(3), 242-249. doi: 10.1001/jama.2009.2012

Ogden, C. L., Carroll, M. D., & Flegal, K. M. (2008). High body mass index for age among US children and adolescents, 2003-2006. *JAMA: The Journal of the American Medical Association, 299*(20), 2401-2405. doi: 10.1001/jama.299.20.2401

Ogden, C. L., Kuczmarski, R. J., Flegal, K. M., Mei, Z., Guo, S., Wei, R., . . . Johnson, C. L. (2002). Centers for Disease Control and Prevention 2000 growth charts for the United States: improvements to the 1977 National Center for Health Statistics version. *Pediatrics, 109*, 45 - 60.

Petersen, A. C., Crockett, L., Richards, M., & Boxer, A. (1988). A self-report measure of pubertal status: Reliability, validity, and initial norms. *Journal of Youth and Adolescence, 17*(2), 117-133.

Pietrobelli, A., Peroni, D. G., & Faith, M. S. (2003). Pediatric body composition in clinical studies: which methods in which situations? *Acta Diabetol, 40*, S270-S273. doi:10.1007/s00592-003-0084-0

Pietrobelli, A., & Tato, L. (2005). Body composition measurements: from the past to the future. *Acta Paediatrica, International Journal of Paediatrics, Supplement, 94*(448), 8-13.

Pischon, T., Boeing, H., Hoffmann, K., Bergmann, M., Schulze, M. B., Overvad, K., . . . Riboli, E. (2008). General and abdominal adiposity and risk of death in Europe. *New England Journal of Medicine, 359*(20), 2105-2120. doi: doi:10.1056/NEJMoa0801891

Power, C., Lake, J. K., & Cole, T. J. (1997). Measurements of long-term health risks of child and adolescent fatness. *Int J Obes Relat Metab Disord, 21*, 507-526. doi:10.1038/sj.ijo.0800454

Prentice, A. M., & Jebb, S. A. (2001). Beyond body mass index. *Obesity Reviews, 2*(3), 141-147. doi: 10.1046/j.1467-789x.2001.00031.x

Radley, D., Cooke, C. B., Fuller, N. J., Oldroyd, B., Truscott, J. G., Coward, W. A., . . . Gately, P. J. (2009). Validity of foot-to-foot bio-electrical impedance analysis body composition estimates in overweight and obese children. *Int J Body Compos Res.*, *7*(1), 15-20.

Reilly, J. J., Dorosty, A. R., & Emmett, P. M. (1999). Prevalence of overweight and obesity in British children: cohort study. *BMJ, 319*(7216), 1039-1039.

Reilly, J. J., Dorosty, A. R., Emmett, P. M., team, A., & Avon Longitudinal Study of Pregnancy and Childhood Study Team. (2000). Identification of the obese child: adequacy of the body mass index for clinical practice and epidemiology. *International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity, 24*(12), 1623-1627.

Reilly, J. J., Methven, E., McDowell, Z. C., Hacking, B., Alexander, D., Stewart, L., & Kelnar, C. J. H. (2003). Health consequences of obesity. *Archives of Disease in Childhood, 88*(9), 748-752. doi: 10.1136/adc.88.9.748

Remsberg, K. E., Demerath, E. W., Schubert, C. M., Chumlea, W. C., Sun, S. S., & Siervogel, R. M. (2005). Early menarche and the development of cardiovascular disease risk factors in adolescent girls: the Fels Longitudinal Study. *Journal of Clinical Endocrinology Metabolism, 90*(5), 2718-2724.

Revenga-Frauca, J., González-Gil, E. M., Bueno-Lozano, G., De Miguel-Etayo, P., Velasco-Martínez, P., Rey-López, J. P., . . . Moreno, L. A. (2009). Abdominal fat and metabolic risk in obese children and adolescents. *J Physiol Biochem., 65*(4), 415-420.

Ross, R., Berentzen, T., Bradshaw, A. J., Janssen, I., Kahn, H. S., Katzmarzyk, P. T., . . . Després, J. P. (2008). Does the relationship between waist circumference, morbidity and mortality depend on measurement protocol for waist circumference? *Obesity Reviews, 9*(4), 312-325. doi: 10.1111/j.1467-789X.2007.00411.x

Roswall, J., Bergman, S., Almqvist-Tangen, G., Alm, B., Niklasson, A., Nierop, A. F. M., & Dahlgren, J. (2009). Population-based waist circumference and waist-to-height ratio reference values in preschool children. *Acta Pædiatrica, 98*(10), 1632-1636. doi: 10.1111/j.1651-2227.2009.01430.x

Ruderman, N., & et al. (1998). The metabolically obese, normal-weight individual revisited. *Diabetes, 47*, 699-713.

Saenz de Rodriguez, C. A., Bongiovanni, A. M., & Conde de Borrego, L. (1985). An epidemic of precocious development in Puerto Rican children. *The Journal of pediatrics, 107*(3), 393-396.

Sardinha, L. B., Going, S. B., Teixeira, P. J., & Lohman, T. G. (1999). Receiver operating characteristic analysis of body mass index, triceps skinfold thickness, and arm girth for obesity screening in children and adolescents. *American Journal of Clinical Nutrition, 70*(6), 1090-1095.

Sarigiani, P. A., Ryan, L., & Petersen, A. C. (1999). Prevention of high-risk behaviors in adolescent women. *Journal of Adolescent Health, 25*(2), 109-119.

Savva, S. C., Tornaritis, M., Savva, M. E., Kourides, Y., Panagi, A., & Silikiotou, N. (2000). Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. *Int J Obes Relat Metab Disord, 107*, 1453-1458. doi:10.1038/sj.ijo.0801401

Schlossberger, N. M., Turner, R. A., & Irwin, C. E. (1992). Validity of self-report of pubertal maturation in early adolescents. *Journal of Adolescent Health, 13*(2), 109-113.

Schmitz, K. E., Hovell, M. F., Nichols, J. F., Irvin, V. L., Keating, K., Simon, G. M., . . . Jones, K. L. (2004). A validation study of early adolescents' pubertal self-assessments. *The Journal of Early Adolescence, 24*(4), 357-384.

Schwandt, P., Kelishadi, R., & Haas, G.-M. (2008). First reference curves of waist circumference for German children in comparison to international values: the PEP Family Heart Study. *World Journal of Pediatrics, 4*(4), 259-266. doi: 10.1007/s12519-008-0048-0

Shen, W., Wang, Z., Punyanita, M., Lei, J., Sinav, A., Kral, J. G., . . . Heymsfield, S. B. (2003). Adipose tissue quantification by imaging methods: a proposed classification. *Obes Res., 11*(1), 5-16.

Siervogel, R. M., Demerath, E. W., Schubert, C., Remsberg, K. E., Chumlea, W. C., Sun, S., . . . Towne, B. (2003). Puberty and body composition. *Horm Res., 60*(Suppl 1), 36-45.

Siervogel, R. M., Wisemandle, W., Maynard, L. M., Guo, S. S., Chumlea, W. C., & Towne, B. (2000). Lifetime overweight status in relation to serial changes in body composition and risk factors for cardiovascular disease: The Fels Longitudinal Study. *Obesity, 8*(6), 422-430.

So, H.-K., Nelson, E., Li, A., Wong, E., Lau, J., Guldan, G., . . . Sung, R. (2008). Secular changes in height, weight and body mass index in Hong Kong Children. *BMC Public Health, 8*(1), 320.

Stettler, N., Zemel, B. S., Kumanyika, S., & Stallings, V. A. (2002). infant weight gain and childhood overweight status in a multicenter cohort study. *Pediatrics, 109*(2), 194-199. doi: 10.1542/peds.109.2.194

Sumter, S. R., Bokhorst, C. L., Miers, A. C., Van Pelt, J., & Westenberg, P. M. (2010). Age and puberty differences in stress responses during a public speaking task: do adolescents grow more sensitive to social evaluation? *Psychoneuroendocrinology, 35*(10), 1510-1516. doi: 10.1016/j.psyneuen.2010.05.004

Sundblom, E., Petzold, M., Rasmussen, F., Callmer, E., & Lissner, L. (2008). Childhood overweight and obesity prevalences levelling off in Stockholm but socioeconomic differences persist. *Int J Obes, 32*(10), 1525-1530.

Sung, R., So, H.-K., Choi, K.-C., Nelson, E., Li, A., Yin, J., . . . Fok, T.-F. (2008). Waist circumference and waist-to-height ratio of Hong Kong Chinese children. *BMC Public Health, 8*(1), 324.

Sung, R. Y. T., Yu, C. C. W., Choi, K. C., McManus, A., Li, A. M. C., Xu, S. L. Y., . . . Fok, T. F. (2007). Waist circumference and body mass index in Chinese children: cutoff values for predicting cardiovascular risk factors. *Int J Obes, 31*, 550-558.

Tam, W. H., Ma, R. C. W., Yang, X., Li, A. M., Ko, G. T. C., Kong, A. P. S., . . . Chan, J. C. N. (2010). Glucose intolerance and cardiometabolic risk in adolescent exposed to maternal gestational diabetes: a 15-year follow-up study. *Diabetes Care*. doi: 10.2337/dc09-2343

Tanner, J. M. (1962). *Growth at adolescence;with a general consideration of the effects of hereditary and environmental factors upon growth and maturation from birth to maturity* (vol. 2nd). Oxford: Blackwell Scientific.

Taylor, R. W., Jones, I. E., Williams, S. M., & Goulding, A. (2000). Evaluation of waist circumference, waist-to-hip ratio, and the conicity index as screening tools for high trunk fat mass, as measured by dual-energy X-ray absorptiometry, in children aged 3–19 y. *The American Journal of Clinical Nutrition, 72*(2), 490-495.

Taylor, S. J., Whincup, P. H., Hindmarsh, P. C., Lampe, F., Odoki, K., & Cook, D. G. (2001). Performance of a new pubertal self-assessment questionnaire: a preliminary study. *Paediatric and perinatal epidemiology, 15*(1), 88-94.

Tell, G. S., Mittelmark, M. B., & Vellar, O. D. (1985). Cholesterol, high density lipoprotein cholesterol and triglycerides during puberty: the OSLO Youth Study *American Journal of Epidemiology, 122*(5), 750-761.

The International Society for the Advancement of Kinanthropometry (ISAK). (2001). International Standards for Anthropometric Assessment Retrieved 22 July, 2011, from http://www.topendsports.com/testing/tests/skinfolds.htm

Thompson, D. R., Obarzanek, E., Franko, D. L., Barton, B. A., Morrison, J., Biro, F. M., . . . Striegel-Moore, R. H. (2007). Childhood overweight and cardiovascular disease risk factors: The National Heart, Lung, and Blood Institute Growth and Health Study. *The Journal of Pediatrics, 150*(1), 18-25.

Tokmakidis, S. P., Christodoulos, A. D., & Mantzouranis, N. I. (2007). Validity of self-reported anthropometric values used to assess body mass index and estimate obesity in Greek school children. *Journal of Adolescent Health, 40*(4), 305-310.

Travers, S. H., Jeffers, B. W., Bloch, C. A., Hill, J. O., & Eckel, R. H. (1995). Gender and Tanner stage differences in body composition and insulin sensitivity in early pubertal children. *Journal of Clinical Endocrinology Metabolism, 80*(1), 172-178.

Turcato, E., Bosello, O., Di Francesco, V., Harris, T. B., Zoico, E., Bissoli, L., . . . Zamboni, M. (2000). Waist circumference and abdominal sagittal diameter as surrogates of body fat distribution in the elderly: their relation with cardiovascular risk factors. *International Journal Of Obesity and Related Metabolic Disorders : Journal of the International Association for the Study of Obesity, 24*(8), 1005-1010.

Tyrrell, V. J., Richards, G. E., Hofman, P., Gillies, G. F., Robinson, E., & Cutfield, W. S. (2001). Foot-to-foot bioelectrical impedance analysis: a valuable tool for the measurement of body composition in children. *International journal of obesity, 25*, 273-278.

Vanhala, M., Vanhala, P., Kumpusalo, E., Halonen, P., & Takala, J. (1998). Relation between obesity from childhood to adulthood and the metabolic syndrome: population based study. *Br Med J, 317*, 319.

Wacharasindhu, S., Pri-Ngam, P., & Kongchonrak, T. (2002). Self-assessment of sexual maturation in Thai children by Tanner photograph. *Journal of the Medical Association of Thailand (Chotmaihet thangphaet), 85*(3), 308-319.

Wang, J. (2003). Waist circumference: a simple, inexpensive, and reliable tool that should be included as part of physical examinations in the doctor's office. *The American Journal of Clinical Nutrition, 78*(5), 902-903.

Wang, J., Thornton, J., Bari, S., Williamson, B., Gallagher, D., Heymsfield, S., . . . Pierson, R. (2003). Comparisons of waist circumferences measured at 4 sites. *Am J Clin Nutr, 77*, 379 - 384.

Wang, Y. (2002). Is obesity associated with early sexual maturation? A comparison of the association in American boys versus girls. *Pediatrics, 110*(5), 903-910. doi: 10.1542/peds.110.5.903

Wang, Y., & Adair, L. (2001). How does maturity adjustment influence the estimates of overweight prevalence in adolescents from different countries using an international reference? *Int J Obes Relat Metab Disord., 25*(4), 550-558.

Wang, Y., & Lobstein, T. (2006). Worldwide trends in childhood overweight and obesity. *Int J Pediatr Obes, 1*(1), 11-25.

Wang, Y., Rimm, E. B., Stampfer, M. J., Willett, W. C., & Hu, F. B. (2005). Comparison of abdominal adiposity and overall obesity in predicting risk of type 2 diabetes among men. *American Journal of Clinical Nutrition, 81*(3), 555-563.

Wang, Z., Patterson, C. M., & Hills, A. P. (2002). A comparison of self-reported and measured height, weight and BMI in Australian adolescents. *Australian and New Zealand Journal of Public Health, 26*(5), 473-478.

Weiss, R., & Kaufman, F. R. (2008). Metabolic complications of childhood obesity: identifying and mitigating the risk. *Diabetes Care., 31 Suppl 2*, S310-316.

Wisemandle, W., Maynard, L. M., Guo, S. S., & Siervogel, R. M. (2000). Childhood weight, stature, and body mass index among never overweight, early-onset overweight, and late-onset overweight groups. *Pediatrics, 106*(1), e14.

Woo, K. S., Chook, P., Yu, C. W., Sung, R. Y. T., Qiao, M., Leung, S. S. F., . . . Celermajer, D. S. (2004a). Effects of diet and exercise on obesity-related vascular dysfunction in children. *Circulation, 109*(16), 1981-1986.

Woo, K. S., Chook, P., Yu, C. W., Sung, R. Y. T., Qiao, M., Leung, S. S. F., . . . Celermajer, D. S. (2004b). Overweight in children is associated with arterial endothelial dysfunction and intima-media thickening. *Int J Obes Relat Metab Disord, 28*(7), 852-857.

World Health Organization. (2006). *WHO Child Growth Standards: height-for-age, weight-for-age, weight-for-length, weight-for-height, and body mass index-for-age: methods and development*. Geneva: World Health Organization.

World Health Organization. (2008). *Waist circumference and waist-hip ratio:report of a WHO expert consultation*. Geneva: WHO Library Cataloguing-in-Publication Data.

World Health Organization. (2010). *WHO Forum and Technical Meeting on Population-based Prevention Strategies for Childhood Obesity*. Geneva, Switzerland: World Health Organization 2010.

World Health Organization. (2011 March). *Obesity and overweight fact sheet N°311* Retrieved 24 July 2011, from http://www.who.int/mediacentre/factsheets/fs311/en/index.html

Wu, W. H., Lee, C. H., & Wu, C. L. (1993). Self-assessment and physicians' assessment of sexual maturation in adolescents' in Taipei. *Zhonghua Minguo Xiao Er Ke Yi Xue Hui Za Zhi, 34*(2), 125-131.

Wu, Y., Schreiber, G. B., Klementowicz, V., Biro, F., & Wright, D. (2001). Racial differences in accuracy of self-assessment of sexual maturation among young black and white girls. *Journal of Adolescent Health, 28*(3), 197-203.

Yan, W., Bingxian, H., Hua, Y., Jianghong, D., Jun, C., Dongliang, G., . . . Da, M. (2007). Waist-to-height ratio is an accurate and easier index for evaluating obesity in children and adolescents. *Obesity, 15*(3), 748-752.

Yusuf, S., Hawken, S., Ounpuu, S., Bautista, L., Franzosi, M. G., & Commerford, P. (2005). Obesity and the risk of myocardial infarction in 27,000 participants from 52 countries: a case-control study*Lancet, 366*, 1640-1649. . doi:10.1016/S0140-6736(05)67663-5

Zachurzok-Buczyńska, A., Klimek, K., Firek-Pedras, M., & Małecka-Tendera, E. (2011). Are metabolic syndrome and its components in obese children influenced by the overweight status or the insulin resistance? *Endokrynol Pol, 62*(2), 102-108.

Zhang, C.-X., Tse, L.-A., Deng, X.-Q., & Jiang, Z.-Q. (2008). Cardiovascular risk factors in overweight and obese Chinese children. *European journal of nutrition, 47*(5), 244-250. doi: 10.1007/s00394-008-0718-7

Zhu, S., Wang, Z., Heshka, S., Heo, M., Faith, M., & Heymsfield, S. (2002). Waist circumference and obesity-associated risk factors among whites in the third National Health and Nutrition Examination Survey: clinical action thresholds. *Am J Clin Nutr, 76*, 743 - 749.

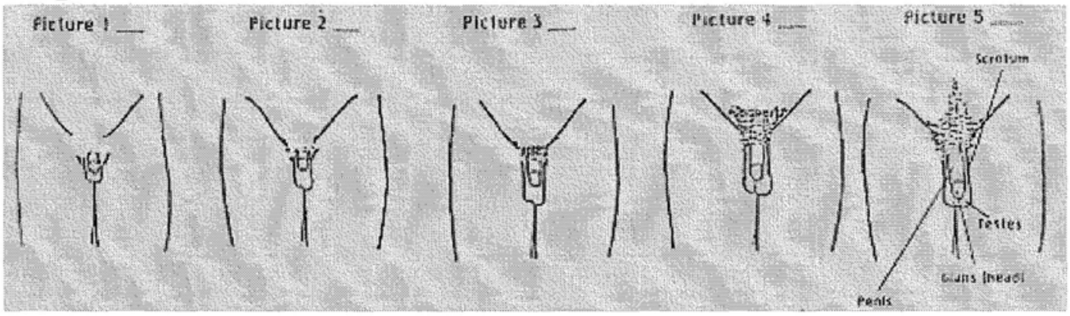
Zimmet, P., Alberti, K. G. M. M., Kaufman, F., Tajima, N., Silink, M., Arslanian, S., . . . Caprio, S. (2007). The metabolic syndrome in children and adolescents – An IDF consensus report. *Pediatric Diabetes, 8*(5), 299-306. doi: 10.1111/j.1399-5448.2007.00271.x

Appendix 2.1 Self-report Tanner pubertal stage questionnaire for boys (Chinese)

姓名：＿＿＿＿＿＿ 班別：＿＿＿ 出生日期：＿＿年＿＿月＿＿日

男性生殖器官發育的自我評估

以下各圖代表男性生殖器官發育的 5 個不同階段（包抱陰莖、陰囊和睪丸）。請細看以下各圖及細閱圖下文字，據你自己身體發育情況，選擇最接近的圖加「√」。



Scrotum ---陰囊; Testes ---睪丸; Penis ---陰莖; Glans (head)---龜頭

圖一： 睪丸、陰囊及陰莖的大小和形狀跟小童一樣

圖二： 睪丸和陰囊比較大，而陰囊較前向下鬆弛及陰囊表皮有改變。 陰莖也比前較大。

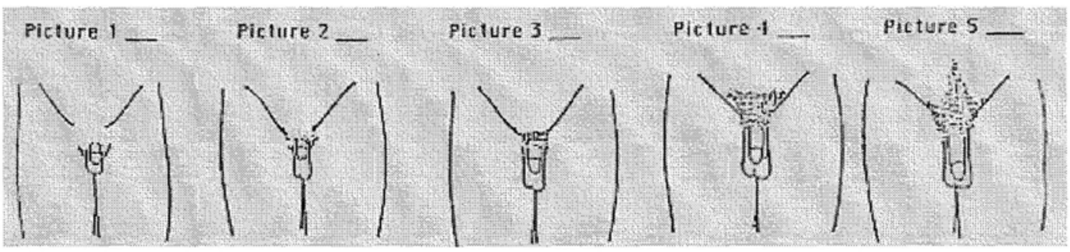
圖三： 陰莖長度增加，而睪丸及陰囊也比較圖二多向下鬆弛。

圖四： 陰莖長度繼續增加及變粗，龜頭也變大。陰囊比前深色，睪丸體積增大。

圖五： 陰莖、陰囊及睪丸的大小和形狀至成年男性模樣。

男性陰毛發育的自我評估

以下各圖代表男性陰毛生長的不同分佈及數量。 請細看以下各圖及細閱圖下文字，據你自己身體發育情況，選擇最接近的圖加「√」。（在選擇適當的圖畫時，請根據陰毛的分佈及數量，而不是根據生殖器官的大小而作出決定）。



圖一：完全沒有陰毛

圖二：有少量長而淺色的毛髮可以是直或曲

圖三：毛髮比較深色及曲，而生長範圍較圖二為大

圖四：毛髮比較粗而生長範圍圖三為大

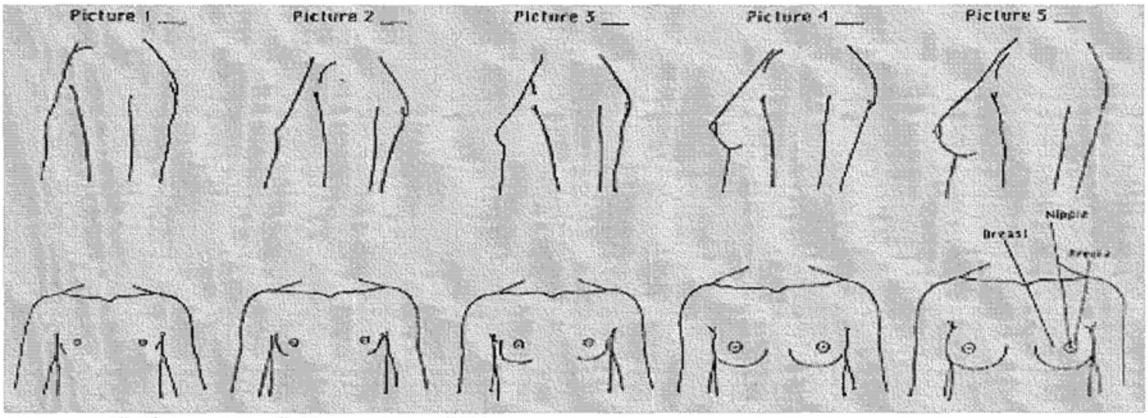
圖五：毛髮生長範圍接近成年男性

Appendix 2.2 Self-report Tanner pubertal stage questionnaire for girls (Chinese)

姓名：______________班別：______ 出生日期：______年____月____日

女性乳房發育的自我評估

以下各圖代表女性乳房發育的 5 個不同階段。 請細看以各圖及細閱圖下文字，根據你自己乳房發育的情況，選擇最接近的圖加上「√」。



Breast ---乳房; Areola ---乳暈; Nipple --- 乳頭

圖一：乳頭有些微突起，乳房其他部份則平坦。

圖二：乳頭比圖一較突起，乳暈比圖一為大，乳房有些微漲起。

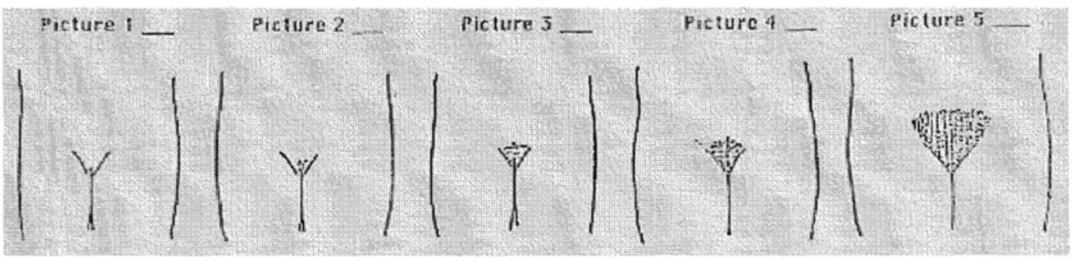
圖三：乳暈和乳房比圖二更大，但乳暈沒有突起現象。

圖四：乳暈及乳頭從乳房的輪廓中突起。（請注意，有些女性沒有圖四的現象，而由圖三直接發展至圖五）。

圖五：乳房完全發育至成年女性樣，乳頭呈現突出，但乳暈變為平坦。

女性陰毛發育的自我評估

以下各圖代表女性陰毛生長的不同分佈及數量。 請細看以下各圖及細閱圖下文字，根據你自己身體發育情況，選擇最接近的圖加上「√」。



圖一：完全沒有陰毛

圖二：有少量長而淺色的毛髮，毛髮可以是直或曲。

圖三：毛髮比較深色及曲，而生長範圍較圖二為大

圖四：毛髮比較粗而生長範圍較圖三為大

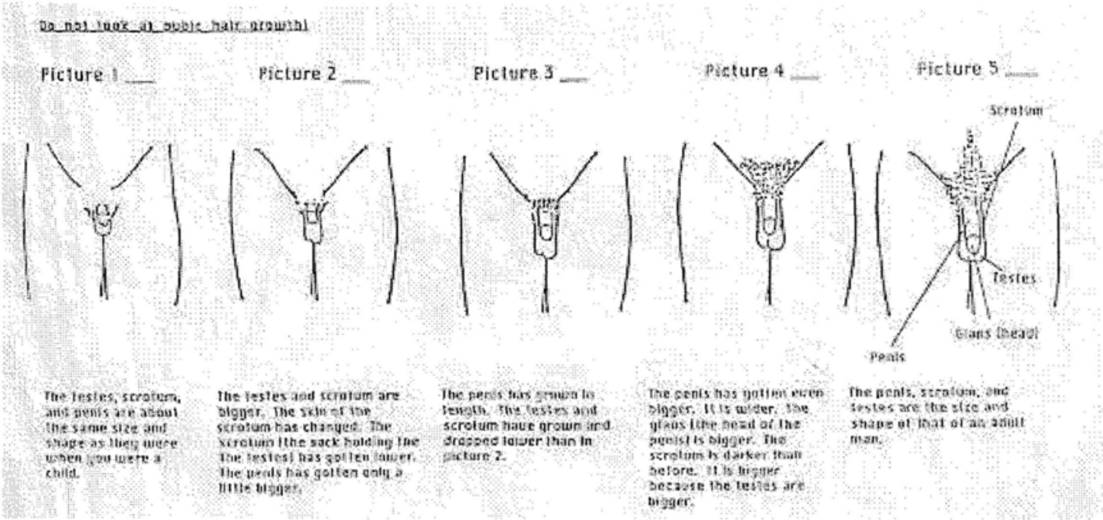
圖五：毛髮生長範圍接近成年女性

Appendix 2.3 Self-report Tanner pubertal stage questionnaire for boys (Morris and Udry, 1980)

Self-report genitalia development for boys

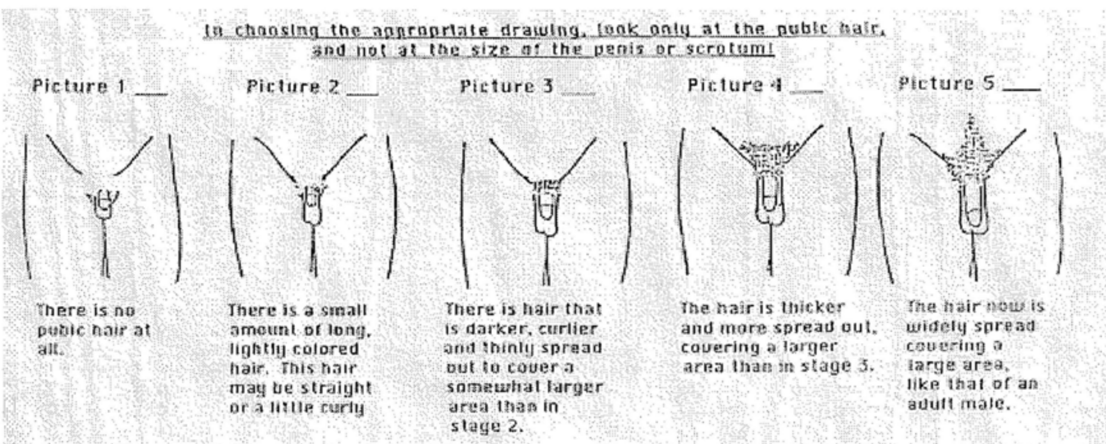
The pictures on this page show different stages of growth of the testes, scrotum, and penis. A boy goes through each of the 5 stages as shown. Please look at each of the pictures. Read the sentences.

Put a [√] on the line above the picture which is closest to your stage of growth.



Self-report pubic hair development for boys (Morris and Udry, 1980)

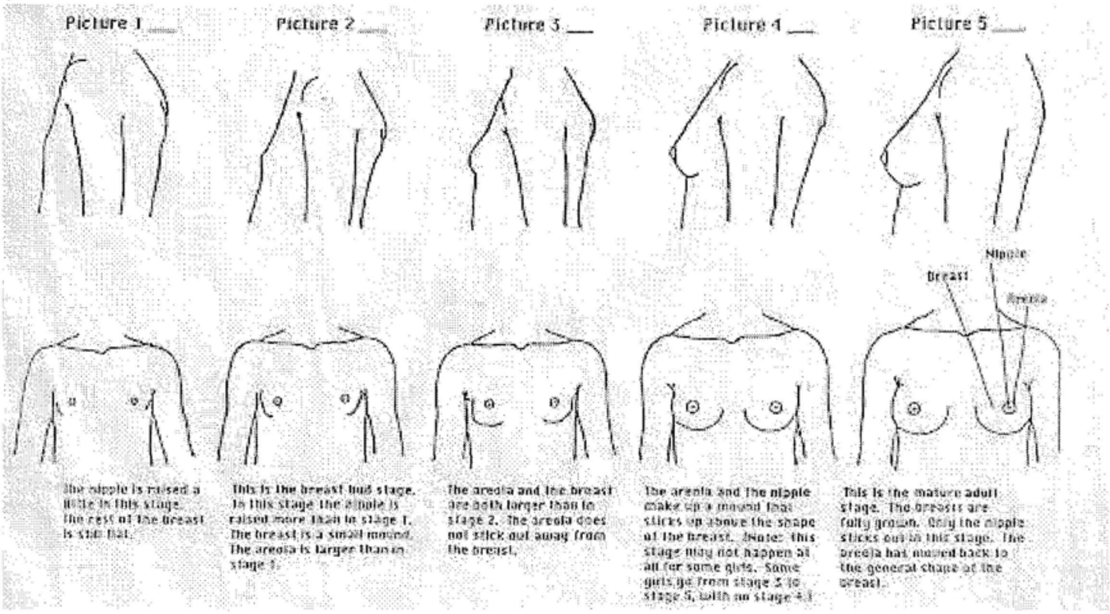
The drawings on this page show different amounts of male pubic hair. Please look at each of the drawings and read the sentences under the drawings. Then check the drawing that is closest to your stage of hair development.



Appendix 2.4 Self-report Tanner pubertal stage questionnaire for girls (Morris and Udry, 1980)

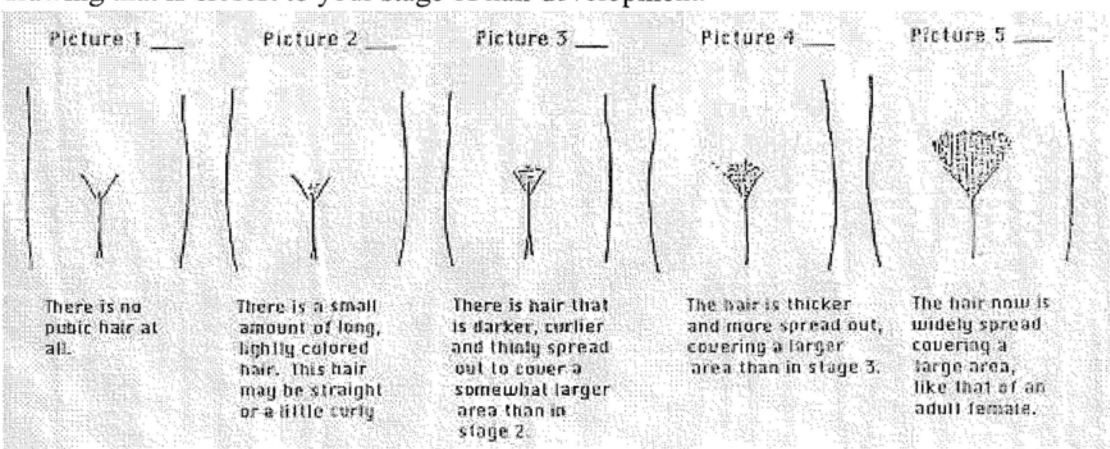
Self-report breast development for girls

The pictures on this page show different stages of how the breasts grow. A girl can go through each of the 5 stages as shown. Please look at each of the pictures. Read the sentences. Put a [√] on the line above the picture which is closest to your stage of growth.



Self-report pubic hair development for girls (Morris and Udry, 1980)

The drawings on this page show different amounts of female pubic hair. Please look at each of the drawings and read the sentences under the drawings. Then check the drawing that is closest to your stage of hair development.



Appendix 2.5 Self-report Pubertal Development Scale for boy (Chinese)

少男發育評估

以下問題關於你身體上的改變。這些都是年青人正常的改變。但發生的年歲會因人而異，請你細閱後才回答。如果你遇上不明白的問題或不知道答案，請選擇“不知道”。

	未有	開始有	已經有	好像已完成	不知道
1. 你有身高上的增長嗎？					
2. 你體毛開始增長了嗎？（體毛是指頭髮以外，身體上其他地方的毛髮。）					
3. 你有皮膚上的改變嗎？例如臉上長出暗瘡？					
4. 你的聲線變沉了嗎？					
5. 你面部開始長出了鬍鬚嗎？					

姓名：____________________年歲：_________

班別：_____________

Appendix 2.6 Self-report Pubertal Development Scale for girl (Chinese)

少女發育評估

以下問題關於你身體上的改變。這些都是年青人正常的改變。但發生的年歲會因人而異，請你細閱後才回答。如果你遇上不明白的問題或不知道答案，請選擇“不知道”。

	未有	開始有	已經有	好像已完成	不知道
1. 你有身高上的增長嗎？					
2. 你體毛開始增長了嗎？（體毛是指頭髮以外，身體上其他地方的毛髮。）					
3. 你有皮膚上的改變嗎？例如臉上長出暗瘡？					
4. 你的乳房開始發育及脹起了嗎？					

5a. 你開始有月經嗎？ 有：______ 未有：______

5b. 如果有的話，你的月經在多少歲開始？ ______歲

姓名：__________________年歲：________

班別：____________

Appendix 2.7 Self-report pubertal development scale (English)

The questions below are about your normal physical and pubertal development changes.
Form for boys:

	not yet started	barely started	definitely started	seems complete	I don't know
1. Would you say that your growth in height:					
2. And how about the growth of your body hair? ("Body hair" means hair any place other than your head, such as under your arms.) Would you say that your body hair growth:					
3. Have you noticed any skin changes, especially pimples?					
4. Have you noticed a deepening of your voice?					
5. Have you begun to grow hair on your face?					

Form for girls:

	not yet started	barely started	definitely started	seems complete	I don't know
1. Would you say that your growth in height:					
2. And how about the growth of your body hair? ("Body hair" means hair any place other than your head, such as under your arms.) Would you say that your body hair growth:					
3. Have you noticed any skin changes, especially pimples?					
4. Have you noticed your breast have begun to grow?					

5a. Have you begun to menstruate (started to have your period)? Yes___ No____

5b. If yes, how old were you when you started to menstruate? _______years old.

Appendix 2.8 Information sheet & consent form for pubertal assessment (Chinese)

香港中文大學兒科學系

兒童及青少年發育評估

研究詳情及同意書

親愛的家長：

香港中文大學兒科學系正進行一項兒童及青少年發育評估的研究，貴子女亦會填寫一份發育自我評估的問卷。若有需要，研究員會讀出問卷內容，讓他了解問卷才作答。同時研究員會為貴子女量度身高，體重，腰圍及發育評估。你孩子的參與，將對香港的兒童及青少年發育期的改變及其有關的問題及學術研究有莫大的裨益。

家長及貴子女參與這項研究純屬自願性質，此項研究所搜集的資料是絕對保密，貴子女可在任何時間退出這項研究。 如有疑問，請電 9672 0440 或傳呼機號碼 7479 8016 陳小姐查詢，並留下你的姓名及聯絡電話。請填回條及交回學校。

謝謝！

香港中文大學

醫學院兒科學系

二零零六年十一月十五日

家長及學童同意書

本人明白以上的資料，並願意本人之兒子/女兒______________________（學童姓名），班別________ 坐號__________。 參與香港中文大學兒童及青少年發育評估的研究。

家長簽名______________ 日期____________________

學童簽名______________ 日期____________________

Appendix 2.9 Information sheet & consent form for pubertal assessment (English)

Dear Parents/Guardian,

The Chinese University of Hong Kong is going to conduct a study concerning the pubertal development of children and adolescents. The aim of this study is to evaluate the validity of self-assessment of pubertal development of children. Your child is invited to participate in this study. Your child's involvement would be beneficial to other children in Hong Kong.

Your child is requested to complete a self-administrated pubertal development questionnaire. Our research team members will read out the questionnaire for your child if necessary. We will obtain your child's body measurements including body weight, body height, waist circumference and pubertal development.

Your child is cordially invited to participate in this study voluntary. All your personal information will be kept confidential. Your child may withdraw from the study at anytime without penalty. Should you have any inquiry, please feel free to contact Ms Chan at 9672 0440 or pager 7479 8016 (please leave your name and contact number).

Thank you for your attention,

Yours faithfully,

The Chinese University of Hong Kong,

Faculty of Medicine,

Paediatrics Department.

Date: 15th Nov., 2006.

Consent form

I understand the above information. I agree my child ______________(name) Class__________ and seat no.______ to participate in the pubertal development assessment study.

Signature:_________________(Parent/ Guardian) Date______________

Signature:_______________(student) Date__________

Appendix 3.1 Information sheet & consent form (Chinese)

香港中文大學內科及藥物治療，兒科及精神科學系
"香港學童睡眠，賀爾蒙失調及肥胖問題研究調查"
研究詳情及同意書（第一部份）

本人衷心邀請閣下及貴子女參加這項研究調查。這項研究旨在探討香港華裔學童(年齡 6 至 18 歲）之睡眠習慣及肥胖的普遍性。在全球各地的兒童及青少年，肥胖的普遍及嚴重性正逐漸上升，越來越多的証據顯示睡眠習慣，賀爾蒙變化及肥胖是有互相關連的。

研究人員將會為貴子女量度身高及體重，檢定身體脂肪比重，以及在空腹八至十小時的情況下，抽取約十毫升血液及尿液樣本。另外，我們會派發問卷給閣下填寫，其內容主要圍繞學童的睡眠健康及與賀爾蒙變化有關的發育自我評估（見附件）。

血液及尿液樣本將用作量定各項與肥胖及心血管疾病相關之檢驗，以及其與睡眠習慣之關係。研究資料將有助醫護人員及教職員計劃適當的預防行動，保障香港學童的健康。

閣下提供的所有個人資料只會用作研究及教學用途，資料絕對保密。閣下所提供的寶貴資料對於香港市民整體的健康改善將有莫大的幫助。

閣下及貴子女參加這項研究全是自願性質的。你可在任何時間退出這項研究。我們將會非常樂意回答你有關此研究之問題。如有任何問題，請致電: 2632 3215。

江碧珊醫生

內科及藥物治療學系副教授

二零零六年十月

本人同意/不同意* 我的子女參加此研究計劃

學童姓名

家長/監護人*姓名

與學童關係

2 個聯絡電話

住址

家長/監護人*簽署

本人願意/不願意* 參加此研究計劃

學童簽署

家長及學童同意書 *刪去不適用者 版本日期: 16.10.2006

Appendix 3.2 Information sheet & consent form (English)

DEPARTMENT OF MEDICINE & THERAPEUTICS, PAEDIATRICS AND PSYCHIATRY,
PRINCE OF WALES HOSPITAL, THE CHINESE UNIVERSITY OF HONG KONG

Sleep duration,
neurohormonal dysregulation and obesity in
Hong Kong children and adolescents

INFORMATION SHEET AND CONSENT FORM (Stage 1)

The prevalence and severity of obesity in children and adolescents is increasing worldwide. Amassing evidence suggests there may be associations between sleep habit, hormones changes and obesity. We aim to conduct this survey to document the pattern of sleep behavior and prevalence of obesity in Hong Kong Chinese school children aged 6-18.

You and your child are cordially invited to participate in this survey. You are requested to complete a questionnaire exploring the sleeping, dietary and physical habits of your child, as well as hormonal related pubertal assessment (see attached). Apart from taking body measurements including body height and weight, waist and hip circumferences, percentage body fat, around 10ml of blood and urine will be collected from your child after 8-10 hours of fasting. Parameters related to obesity and cardiovascular risk factors will be examined in the blood and urine samples. These data will help our health care workers and educators to design programs to promote the general fitness of our children. All data will be analyzed in an anonymous manner and used for research and educational purposes. Your assistance in this important program in our attempt to improve the health and quality of life of our local population is much appreciated. Your child and your participation in this study are voluntary. You may withdraw from the study at any time without penalty. We will answer any questions you have about this study before, during and after the study. For enquiry, please contact Dr. Kong at telephone number: 2632 3125.

Dr. Alice Pik Shan Kong
Associate Professor
Department of Medicine and Therapeutics
The Chinese University of Hong Kong
16 Oct 2006

Parental and Children Consent form

I agree/disagree* to my child participating in the survey	
Name of child	
Name of parent / guardian*	
Relationship with child	
2 Contact telephone numbers	
Address	
Signature of parent / guardian*	
I agree/disagree* to participate in the survey	
Signature of child	

* delete as appropriate

Appendix 3.3 Report on physical examination and blood test results

Sleep duration, neurohormonal dysregulation and growth in
Hong Kong children and adolescents
Department of Medicine and Therapeutics, Paediatrics and Psychiatry
Prince of Wales Hospital
The Chinese University of Hong Kong
香港中文大學威爾斯親王醫院內科及藥物治療學系，兒科及精神科學系
香港學童睡眠，賀爾蒙失調及成長問題研究調查

我們衷心感謝閣下及貴子女参加這項研究調查。以下是貴子女的檢查結果。因本地參考標準尚待確立，檢查結果只供參考。如有明顯地不正常之報告，我們的研究員/醫生會作個別通知及跟進。閣下如對檢查結果有任何問題，可向你們的家庭醫生查詢或致電：2632 2648，謝謝！

江碧珊醫生

內科及藥物治療學系副教授

<u>檢查報告</u>

Ref code 参考編號	: KPS20xx	
School Name 學校名稱	: xxxx 小學	
Assessment Date 檢查日期	:	
Name 姓名	: LAW xx 羅 xx	
ID No. 香港身份證號碼	: UWxxxxxxx	
Sex 性別	:	
Age 年齡	:	
Body Weight 體重	:	公斤
Body Height 身高	:	米
Body Mass Index 體重指數	:	kg/m^2
Blood Pressure 血壓 (SBP 上壓)	:	mmHg
(DBP 下壓)	:	mmHg
Pulse rate 脈搏	:	/每分鐘
Body fat 身體脂肪	:	%

Laboratory Results 化驗報告

			單位
CBC 全血圖	RBC 紅血球	:	10^12/L
	Haemoglobin 血色素	:	g/dL
	Platelet Count 血小板	:	10^9/L
	WBC 白血球	:	10^9/L
Lipids 血脂肪	Cholesterol 膽固醇	:	mmol/l
	TG 三酸甘油脂	:	mmol/l
	HDL-C 高密度膽固醇	:	mmol/l
	LDL-C 低密度膽固醇	:	mmol/l

Assessment Date 檢查日期 :

Name 姓名 : LAW xx **羅** xx

ID No. 香港身份證號碼 : UWxxxxxxx

Sex 性別 :

Age 年齡 :

Laboratory Results 化驗報告

			單位
RFT 腎功能	Sodium (Na) 鈉	:	mmol/l
	Potassium (K) 鉀	:	mmol/l
	Urea 尿素	:	mmol/l
	Creatinine 肌酸酐	:	umol/l
LFT 肝功能	Total Protein 總蛋白質	:	g/l
	Albumin 白蛋白	:	g/l
	Total Bilirubin 總膽紅素	:	umol/l
	Total ALP 鹼性磷酸酶	:	IU/l
	ALT/GPT 谷丙轉氨酵素	:	IU/l
	GGT 丙種谷氨酸轉肽酶	:	U/l
	Urate 尿酸	:	mmol/l
Fasting Blood Glucose 空腹血糖		:	mmol/l
Spot Urine 小便分析	Urine Creatinine 尿肌酸酐	:	mmol/l
	Urine Albumin 尿白蛋白	:	mg/l
	Urine Alb/Creat Ratio 蛋白尿	:	mg/mmol

總結:

體重　:　稍輕/正常/過重/肥胖

血壓　:　稍低/正常/稍高/高

腎功能　:　正常/不正常

肝功能　:　正常/不正常

尿酸　:　正常/不正常

血脂肪　:　正常/不正常

貧血　:　無/有

蛋白尿　:　無/有

糖尿病　:　無/有

備註　:　____