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From Showcards to Mobile Technology: Novel Tools in Monitoring and Preventing Obesity and Non-Communicable Diseases

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From Showcards to Mobile Technology:
Novel Tools in Monitoring and Preventing Obesity and Non-Communicable Diseases

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Novel Tools in Monitoring and Preventing Obesity and Non-Communicable Diseases

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pour le Doyen
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…to my husband Ramon

Abstract (English)

Obesity and chronic diseases are major global health concerns. Monitoring obesity trends, understanding its social determinants and implementing innovative approaches to prevent obesity and chronic diseases represent major challenges in public health.

Using a multi-disciplinary approach in the context of four different research studies, this thesis project aims to: 1) validate a showcard tool based on "Pulvers' silhouettes" as a measure of obesity in an African population, 2) examine the potential mediating role of idealized body size in the relationship between socioeconomic status and obesity in an African population, 3) evaluate the penetration and mobile technology (mobile phone, internet, etc.) and acceptance for receiving health related SMS messages, in the perspective of using mobile technology for health intervention (mHealth) in an African population, and 4) develop a target specific mobile health application and assess its effectiveness in encouraging healthier food choices in Switzerland.

These studies reveal a number of novel and interesting findings. 1) the ethnic-specific Pulvers' silhouette show card can predict obesity in an African population and serve as a proxy for anthropometric measure in postal or digital survey settings. 2) Ideal body size plays a mediating role in the association of obesity and socioeconomic status. 3) there is a ubiquitous mobile phone ownership and good acceptance for mHealth initiative in Seychelles, especially among women and young adults. Finally, 4) mobile application designed to provide nutrition transparency highlighted the key role of informative and interpretative labelling format in encouraging healthier food choices.

Together these four studies address novel tools in monitoring obesity and its associated social determinants, and highlight the innovative approaches mobile technology can serve in future public health research, disease prevention and health promotion strategies.

Abstract (Français)

L'obésité et les maladies chroniques représentent un problème de santé publique majeur à l'échelle mondiale. Surveiller les changements dans la prévalence de l'obésité, examiner ses déterminants sociaux, ainsi que d'implémenter des interventions pour réduire la prévalence de l'obésité et les maladies chronique représentent certains des défis en santé publique.

En utilisant un approche multidisciplinaire sur quatre études, ce travaille de thèse vise à : 1) valider le « Pulvers' silhouette showcard » comme un outil de détection de l'obésité dans les populations Africains, 2) examiner le rôle de « taille du corps idéalisée » dans la relation entre le statut socioéconomique et l'obésité en Afrique, 3) évaluer la pénétration de la technologie mobile et l'acceptation des messages SMS pour des éventuelles interventions de santé dans les pays en développement, et finalement 4) développer et tester d'efficacité d'une application mobile ciblé afin d'encourager des choix alimentaires sains.

Destiné à la surveillance des tendances de l'obésité et ses déterminants sociaux, cette thèse a validé Pulvers' silhouette tant qu'un proxy pour la détection de l'obésité dans la population africaine. Les Silhouettes ont servi à offrir de nouvelles perspectives sur le rôle de la taille du corps idéalisé dans l'association entre le statut socioéconomique et l'obésité. Une analyse de la pénétration de la technologie mobile au Seychelles a démontré le potentielle rôle des messages SMS ensemble avec des communications télévisé dans la prévention de l'obésité et les maladies chroniques auprès des différents groupes socio-économique. Enfin, le développement et l'essai pilotage d'une application mobile conçu pour offrir la transparence de la nutrition a souligné le rôle clé du format de l'étiquetage permettant des choix alimentaires sains chez les jeunes adultes

Ensemble, ces quatre études portent sur de nouvelles approches dans le suivi de l'obésité et de ses déterminants sociaux associés, et soulignent la technologie mobile parmi des approches novatrices dans la recherche en santé publique, ainsi que dans la prévention des maladies et des stratégies de promotion de la santé.

Part I. Silhouettes showcards

Novel tools for monitoring obesity
and its socioeconomic determinants

Introduction

The rapid rise in obesity prevalence and chronic diseases are major global health concerns. This has sparked a growing interest in understanding the underlying determinants of obesity. The factors influencing changes in body size are multifaceted and complex. They involve individual physiology, psychology, lifestyle choices, and social norms, as well as geographical and environmental factors. Understanding these factors and the relationships between them can offer insights needed in design and development of preventive interventions.

Since 1980, the global prevalence of obesity has doubled [1]. It is estimated that in 2008 about 1.4 billion adults, 18 years and older, were overweight, and more than 500 million adults were classified as obese [1]. With increasing adiposity, there are numerous known adverse metabolic effects such as hypertension, dyslipidemia and insulin resistance (Figure 1). These metabolic abnormalities result in an increased risk of coronary heart disease, ischemic stroke and type 2 diabetes mellitus, as well as certain cancers and respiratory diseases [2], collectively known as non-communicable diseases (NCDs). It is estimated that in 2012, 68% of all deaths globally were due to NCDs and two thirds of all premature deaths due to NCDs occur in low middle income countries (LMIC) [1].

Once associated with high-income countries (HIC), obesity is now a growing concern in LMICs. Aside from increasing number of obese individuals in developing countries, there appears to be important differences in the association of body size with gender and socio-economic status between HICs and LMICs [3-5]. While overweight and obesity are generally more prevalent among persons with lower socioeconomic status (SES) in HICs, the reverse pattern is typically found in low-income countries (LICs) [3, 4]. Moreover, within-country shifts in overweight and obesity from higher to lower SES groups tend to occur faster and at earlier levels of economic development for women than for men, which suggests important interactions of SES and gender in shaping individual body sizes [3-5].

The consequences of obesity are not limited to poor physical health. Evidence from several large scale studies indicates a number of important psychological consequences, such as depression and anxiety [6, 7]. Numerous studies have indicated that overweight/obese children are at an increased risk of negative psycho-social consequences that may also contribute to low self-esteem, depression, body dissatisfaction, and eating disorders [8, 9]. For example, childhood psychological distress arising from weight stigma has shown to have an important negative impact on quality of adult life, including but not limited to areas such as marital status, education, employment, healthcare and social relationships [10-17]. Together these physical and psychological consequences of obesity have a considerable economic burden on financial resources, both at the individual level as well as for society.

The direct costs associated with obesity include hospitalisation, laboratory and drug therapy in diagnosis and treatment of obesity related complications, including but not limited to NCDs. These costs represent the tip of the iceberg compared to the indirect costs of obesity due to value of lost work resulting from absenteeism, sick leave and premature death of qualified professionals. In a recent literature review Withrow and Alter (2011) estimated that obese individuals have medical costs that were approximately 30% greater than their normal weight peers [18]. Using a simulation model, Wang and colleagues (2011) estimated that in the next two decades, obesity will affect 65 million more adults in the USA and 11 million more adults in the UK [19]. They projected the combined medical costs associated with treatment of obesity-related diseases will result in an estimated increase of $48–66 billion/year in the USA and by £1·9–2 billion/year in the UK [19]. Other studies examined the cost of obesity and NCDs in developing countries and concluded that if no measure is taken to reduce morbidity and mortality associated with obesity, the cumulative economic burden of NCD will reach an estimated US $7 trillion by 2025 in LMICs alone [20].

To address these growing global health and economic concerns, WHO has defined a clear action plan under its “Global Strategy for the Prevention and Control of Non-communicable Diseases” to establish and strengthen initiatives for the surveillance, prevention and management of

NCDs, including obesity [1]. These recommendations include close monitoring of obesity trends over time in all segments of the population and to use innovative solutions to reduce obesity prevalence through behavior change, social policies and environmental interventions.

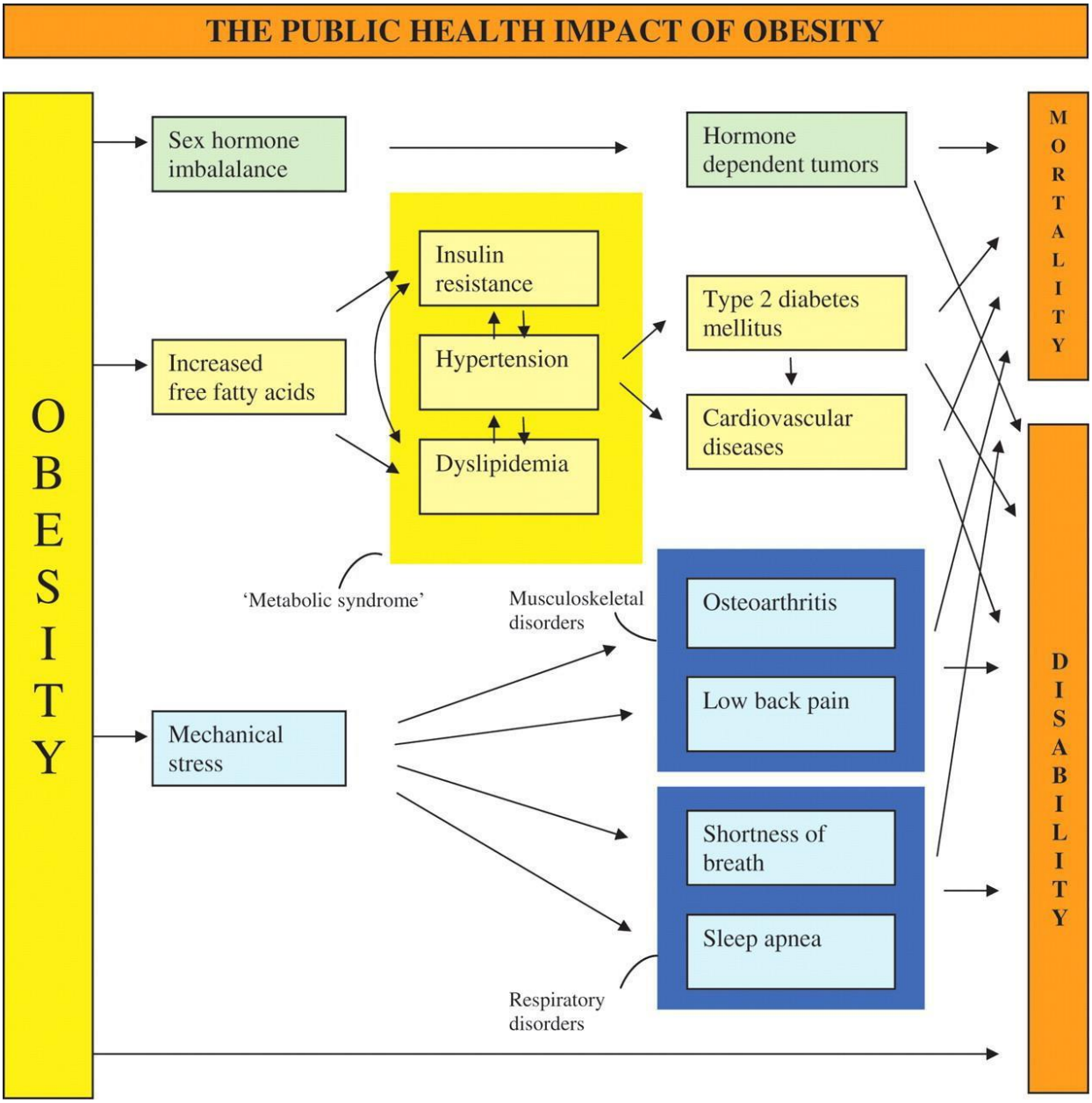

Figure 1: Public health impact of obesity, Visscher & Seidell [21], with permission from the European Heart Journal

Monitoring obesity

Body mass index (BMI)

The rising prevalence of obesity and the associated physiological and psychological complications has sparked substantial interest in the routine measurement of body size and adiposity in public health research, epidemiological studies, as well as general-purpose surveys in social science and health economics. Clinical definition of overweight and obesity is characterized as excess body fat accumulated in adipose tissue and other organs. Epidemiologic studies commonly use body mass index (BMI), a ratio of weight (in kg) divided by height squared (in meters) [22], as an indicator of adiposity.

The World Health Organisation (WHO) has established classification specifications with BMI of 18-24.9 as "normal weight", BMI of 25-29.9 as "overweight" and BMI of 30 or greater as "obese"[23]. The main assumption of these guidelines is that higher BMI is associated with higher body fat percentage and its associated morbidity and mortality. However, numerous studies have shown BMI misclassification resulting from variation in body composition for example, high muscle mass resulting in obese BMI, with others within normal BMI range may have very high body fat composition [24].

The effectiveness of BMI in describing adiposity depends on its correlation with more direct measures of adiposity such as fat mass (FM), subcutaneous adipose tissue (SAT), or visceral adipose tissue (VAT). In recent years, numerous studies have compared the performance of BMI with more accurate measures of body composition such FM, SAT and VAT using dual energy X-ray absorptiometry, hydrostatic weighing, air-displacement plethysmography, isotope dilution, and bioelectrical impedance analysis both in children and adult population [25-33]. There are a number of strengths and weaknesses of each approach in detecting adiposity compared to BMI. In a meta-analysis of the literature, Okorodudu and colleagues calculated the pooled sensitivity and specificity of BMI as a measure of adiposity, and showed that commonly used BMI cut-off values to diagnose obesity have high specificity, but low sensitivity and fail in identifying excess adiposity in half of people with excess body fat [28].

Other studies have shown that adiposity at a given BMI tends to significantly vary across gender, age, and race-ethnicity [34-36] which reduces the transferability of BMI measures across different cultures. For example, in a meta-analysis, Deurenberg and colleagues [37] suggested that obesity cut-off values for Asians, including Indonesians, should be 27 kg/m2. Gallagher and colleagues [38] went on to develop sex-specific formulas for estimating relative body fatness from BMI and other potential independent variables such as age and ethnicity. Despite existing controversy around BMI as a measure of adiposity as well as its relationship with numerous alternate measures available for detecting adiposity, BMI remains the golden standard and continues to dominate as the obesity indicator in public health research due to its measuring simplicity in clinical and field settings.

Abdominal obesity

Abdominal obesity is increasingly recognized as a major risk factor for cardiovascular disease (CVD). Compared with body mass index (BMI), anthropometric measures of abdominal obesity [e.g. waist circumference (WC), waist-to-hip ratio (WHR), sagittal abdominal diameter (SAD), or waist to stature ratio (WSR)] appear to be more strongly associated with metabolic risk factors [39], incident CVD events, and death [40, 41]. Additionally, evidence indicates that BMI coupled with waist circumference is a better predictor of obesity related health risks than BMI alone [42, 43]. However controversy still remains regarding the relationship between anthropometric indices and body fatness. For example, Flegal and colleagues [24] found that WC and WSR did not perform better than BMI as an adiposity measure and these measures are more related to each other than to percent body fat of an individual [24].

Total body fat percent

Total body fat (TBF) and percent body fat (PBF) measures using bioelectrical impedance analysis (BIA) are appealing measures of body composition in clinical and field settings, as BIA is non-invasive, rapid, portable, cost-efficient, and easy to operate without extensive training. Body

composition and validation studies using BIA have shown benefits of BIA in predicting adiposity and its close association in glucose homeostasis and inflammatory response [44, 45]. However such instruments are also criticized as different models offer a wide range of precision variation and their use in assessment of adiposity can vary according to hydration status [46]. While the research on the assessment of body composition in laboratory and field settings continue and more modern tools for measuring body size are available; certain studies, due to lack of available resources, rely on self-reported weight and height information.

Self-reported measures

In resources-limited settings, a common alternative to anthropometric measurement for assessing individuals' body size and obesity is to simply ask respondents about their weight and height and compute their BMI based on self-reported information. While self-report of weight and height is clearly less costly than anthropometric measures in terms of survey time, equipment, interviewer training, and respondent burden; their general reliability has often been questioned [47].

Many health interview surveys as well as online or mobile-based surveys include questions on self-reported weight and height to monitor obesity trends. Compared to measured anthropometrics, self-reported weight commonly suffers from significant underreporting, while self-reported height tends to be over-reported, especially among older persons and when comparing men to women [48-52]. Underreporting of weight and over-reporting of height represent mutually reinforcing measurement errors when computing body size as a function of weight for height, which is often further exacerbated through the use of non-linear transformations as in the case of computation of BMI defined as body mass divided by the square of body height. Moreover, people with limited literacy often do not know their true weight and height, which can result in significant item non-response and/or low-quality self-reported measures [52].

Silhouettes showcards

In recent studies, self-reported measurements have been replaced with gender and ethnic specific tools such as silhouettes, a showcard with images of increasing body sizes. Originally developed by Stunkard and colleagues [53], silhouette showcards, which depict a series of pictures of distinct body sizes, represents an easy visual tool for measuring perceived body size in general-purpose survey settings. Silhouette showcards display sex-specific body sizes, typically in ascending order of BMI (Figure 2) [54]. To measure body size, respondents are asked to pick the picture that best represents their own body size. Given the diversity of body sizes by ethnicity, a collection of ethnically-specific silhouette showcards including the original Stunkard silhouettes [53] have been developed and validated as a measure of body size in different populations such as Asians [55, 56], Europeans [57-59], and North and Latin Americans [60-62]. Pulvers and colleagues [63] developed a modified version of these silhouettes based on distinct morphology of African population and used it for body size studies amongst African Americans [64-66].

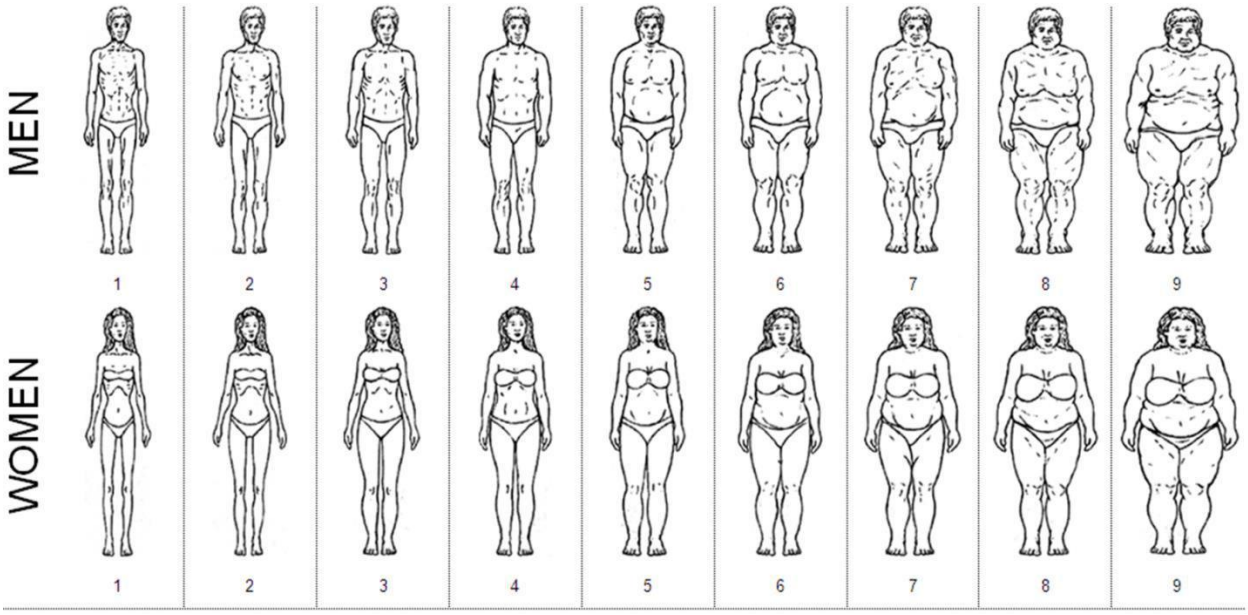

Figure 2: Pulvers' Silhouettes Showcard designed for population of African descent [63]

Measuring actual body size

Age-, sex-, and ethnic-specific silhouettes have been used to measure self-reported body size as well as in studies of socio-cultural influences on body image satisfaction or dissatisfaction and its relation to obesity and eating behaviour [67]. Body image is a complex relationship between internal perception of own appearance in relation to the influence of outside world on those perception with a strong impact on behaviour [68]. As a result, there is growing interest in the role of perceived body image in other fields such as psychology, social and behavioural sciences, as well in public health, where silhouettes have shown to serve as a valuable research tool.

Measuring ideal body size

Besides assessing respondents' perceived actual body size, silhouettes have also been used to measure other important concepts in health psychology and nutritional science. Ideal body size is used to assess body size dissatisfaction as a potential motivating factor for losing weight through increased exercise or dieting [69-72]. A number of theories in health psychology such as the health belief model, the theory of reasoned action or the theory of planned behaviour suggest that health-related attitudes and beliefs at the individual level are important determinants of behavioural intentions, behaviours and health outcomes [73]. Similarly, the goal setting theory suggests that goals are immediate regulators of behaviour. Perceived ideal body size is considered an important factor in the development of an action plan, which in turn, motivates and facilitates the actual adoption of weight control behaviours [74]. At the same time, there is evidence that various social influences can affect behavioural goals [75], which may lead to attitudinal differences in perceived ideal body size across gender, cultural contexts and over time. [76, 77]. Studies have shown that idealized body size is strongly influenced by exposure to different cultural contexts and values. For example, identification with some Asian cultures appears to be related to thinner body ideals, whereas identification with African cultures seems to be associated with larger body ideals [78]. Therefore a better understanding of factors influencing cultural and racial differences in body image is needed for promotion of healthy behaviour and prevention of eating disorders or obesity.

Ideal body size as a determinant of obesity

It has been shown that perceived health status or ideal body size is likely influenced by the prevalence of obesity as well as cultural differences in acceptance of larger body sizes [79, 80]. For example, through a qualitative study, Mvo and colleagues showed the overall acceptance of larger body sizes in African women [81]. Others have shown the important role of race, ethnicity

and social norms in shaping body sizes idealized by women and men [76, 82]. In addition to racial differences, Lynch and colleagues highlighted the socioeconomic differences in ideal body size where lower education was associated with higher body ideals amongst black women [83]. Moreover, within-country variation in overweight and obesity by socioeconomic status tends to suggest important interactions of SES and gender in shaping individual body sizes [3-5].

Aim of two silhouette studies

Through two separate studies, this first part of the thesis assesses the validity of Pulvers' silhouettes as a measure of actual body size and examines the mediating role of ideal body size in the social pattern of obesity observed in Seychelles, a middle income country in the African region.

Paper 1: Validity of Pulvers' silhouette showcard as a measure of body size and obesity

Based on a population survey in an African population, Pulvers' silhouettes validity is compared to five established adiposity measures, namely BMI, waist to hip, waist to height, fat percent and abdominal obesity. The study assesses the sensitivity and specificity of this ethnic- and gender-specific tool in detecting obesity, as per a BMI of 30 or greater, in African adults compared to other anthropometric measures.

Paper 2: Ideal body size as a mediator between socioeconomic status and body mass index

Using Pulvers' silhouette showcard to measure participants' ideal body size, this second study assesses socioeconomic differences in ideal body size in adult men and women. By means of mediation analysis, the findings show a mediating role of ideal body size in the observed gender differences and social patterns of obesity in developing countries.

Survey

A population-based survey was conducted in 2013 in the Republic of Seychelles, an archipelago of more than a hundred islands located in the Indian Ocean east of Kenya. At the time of the survey, the Seychelles is an upper middle income country with a population of 92,000 (WHO 2013), the smallest population of any African state, of which 54% live in urban areas. The country's gross national income per capita is 14,100 (US dollars, World Bank Atlas method, 2014) and the majority of the population is of African descent. The study sample consisted of 1240 persons aged 25–64 years, randomly selected. The participation rate of the study was 73%.

The survey consisted of two components: (1) a face-to-face interview, which elicited information on respondents' characteristics, including their socio-demographic status (age, education, income), followed by (2) a health examination comprising a series of anthropometric measurements such as measured height and weight, waist circumference, and body fat percent as well as other health measures. The face-to-face interview survey contained self-reported ranking of actual and ideal body size using the sex- and ethnicity-specific Pulvers' silhouette showcard [21].

Summary of findings

The findings from the first study showed the comparability of silhouettes to other anthropometric measure of adiposity. Moreover, silhouettes accuracy in detecting obesity (as per the standard cut-off BMI of 30) using sex-specific ROC analysis resulted in an area under curve (AUC) of 0.91 in men and 0.89 in women. These AUC values were similar to those of waist

circumference (AUC of 0.95 in men, and 0.94 in women), fat percent (AUC of 0.94 in men and women), and waist to height ratio (AUC of 0.95 in men and 0.94 in women) for detecting obesity (BMI>30). The overall discriminatory power of silhouettes to detect obesity was thereby very high and similar in both men and women. Additionally, silhouettes and measured BMI detected similar magnitude, direction and significance of association in the socioeconomic pattern of obesity.

In the second study, using the classic sequence of regressions for mediation analysis, and keeping age and SES fixed, we found that reporting a one unit higher perceived ideal body size was associated with an estimated 3.1 kg/m^2 higher actual body size for both genders. In addition, incorporating perceived ideal body size into a multivariable model for actual BMI led to a significant attenuation of both the positive SES-BMI relationship among men and the negative SES-BMI relationship among women. For men, only income remained statistically significant once perceived ideal body size was incorporated into the model, whereas all three SES indicators remained statistically significant in women. We found the relationship of ideal body size to be consistent with the gender-specific associations between SES and actual body size as measured by BMI.

Discussion

Our study validates Pulvers' silhouette body size showcards as a simple measure for body size and adiposity in the adult population in the African region. Our findings reveal self-reported silhouette rankings to be comparable to other measured body size and adiposity indicators such as measured BMI, fat percent, waist circumference, and waist to height ratio. In addition, our analyses show that silhouettes are also able to capture the social patterning of body size. The latter is particularly important in general-purpose social science survey settings, where the social patterning of body size is often of key interest.

We used the validated Pulvers' silhouettes to assess the role of ideal body size in the socioeconomic pattern of obesity. Using mediation analysis, we found ideal body size to play a mediating role on the relationship between SES and BMI with a contrasting effect of perceived

ideal body size in men and women. Our findings suggest the gender-specific relationship between SES and BMI to be partially mediated through differences in ideal body size. These findings highlight the importance of addressing attitudes and social norms regarding body size when planning health promotion and obesity prevention programs or policies.

Together the two studies revealed the utility of self-reported silhouette rankings as a valid proxy for measured body size and ideal body size, as well their relationship with socioeconomic status

Appendix 1

Validity of silhouette showcards as a measure of body size and obesity in a population in the African region: A practical research tool for general-purpose surveys

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RESEARCH Open Access

Validity of silhouette showcards as a measure of body size and obesity in a population in the African region: A practical research tool for general-purpose surveys

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Abstract

Background: The purpose of this study is to validate the Pulvers silhouette showcard as a measure of weight status in a population in the African region. This tool is particularly beneficial when scarce resources do not allow for direct anthropometric measurements due to limited survey time or lack of measurement technology in face-to-face general-purpose surveys or in mailed, online, or mobile device-based surveys.

Methods: A cross-sectional study was conducted in the Republic of Seychelles with a sample of 1240 adults. We compared self-reported body sizes measured by Pulvers' silhouette showcards to four measurements of body size and adiposity: body mass index (BMI), body fat percent measured, waist circumference, and waist to height ratio. The accuracy of silhouettes as an obesity indicator was examined using sex-specific receiver operator curve (ROC) analysis and the reliability of this tool to detect socioeconomic gradients in obesity was compared to BMI-based measurements.

Results: Our study supports silhouette body size showcards as a valid and reliable survey tool to measure self-reported body size and adiposity in an African population. The mean correlation coefficients of self-reported silhouettes with measured BMI were 0.80 in men and 0.81 in women ($P < 0.001$). The silhouette showcards also showed high accuracy for detecting obesity as per a BMI ≥ 30 (Area under curve, AUC: 0.91/0.89, SE: 0.01), which was comparable to other measured adiposity indicators: fat percent (AUC: 0.94/0.94, SE: 0.01), waist circumference (AUC: 0.95/0.94, SE: 0.01), and waist to height ratio (AUC: 0.95/0.94, SE: 0.01) amongst men and women, respectively. The use of silhouettes in detecting obesity differences among different socioeconomic groups resulted in similar magnitude, direction, and significance of association between obesity and socioeconomic status as when using measured BMI.

Conclusions: This study highlights the validity and reliability of silhouettes as a survey tool for measuring obesity in a population in the African region. The ease of use and cost-effectiveness of this tool makes it an attractive alternative to measured BMI in the design of non-face-to-face online- or mobile device-based surveys as well as in-person general-purpose surveys of obesity in social sciences, where limited resources do not allow for direct anthropometric measurements.

Keywords: Silhouette body size showcard, Obesity, Anthropometric measure, Africa, Social survey, General purpose household surveys, Socioeconomic status

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Introduction

The rising prevalence of overweight and obesity around the world has sparked substantial interest in the routine measurement of body size and obesity in general-purpose social science surveys. Besides their well-documented role as a risk factor for many adverse health outcomes such as cardiovascular diseases or diabetes [1] or mortality [2], body size and obesity are also commonly associated with important demographic, economic, psychological, and social outcomes such as marital status, productivity and wages, psychological distress, quality of life, and stigma, to name a few [3–10]. Given this wide-ranging role of body size and obesity in determining individual welfare and quality of life, its measurement should not be limited to epidemiological and health studies, but should also become a standard aim of general-purpose social science population surveys.

Obtaining cost-effective yet reliable measures of weight status is, however, often challenging in the context of general-purpose surveys, especially in resource-constrained settings [11]. While measured weight and height remain the gold standard for determining body mass index (BMI) in epidemiological and health studies, many general-purpose social science surveys lack such anthropometric measures due to considerations of survey cost, respondent burden and survey time. Specifically, measured weight and height, as well as complementary measures such as waist and hip circumference, provide reliable assessments of individuals' body size and obesity; however, they often require a considerable share of (generally limited) survey time, use of specific equipment and know-how for measurement such as weighting scales and stadiometers and trained staff, and impose substantial burden on respondents by requiring them to take off their shoes and (heavy) clothing to obtain accurate measurements [12, 13]. This may be also difficult or impossible to perform in some cultural contexts. Similarly, taking such measurements is generally not feasible in the context of mail and online- or mobile device-based surveys, which require body size measurement based on self-reports. As a result, many general-purpose social science surveys do not contain direct anthropometric measurements of respondents' weight and height in the face of binding resource constraints and competing survey demands.

A common alternative to anthropometric measurement for assessing individuals' body size and obesity is to simply ask respondents about their weight and height and compute their BMI based on these self-reports. While self-reports of weight and height are clearly less expensive than measured anthropometrics in terms of survey time, equipment, interviewer training, and respondent burden, their general reliability has often been questioned, especially in studies of older individuals or settings with relatively low levels of literacy [14]. Compared to measured anthropometrics, self-reported weight commonly suffers from significant underreporting, while self-reported height tends to be over-reported, especially among older persons and when comparing men to women [15–19]. Underreporting of weight and over-reporting of height represent mutually reinforcing measurement errors when computing body size as a function of weight for height, which is often further exacerbated through the use of non-linear transformations as in the case of computation of BMI defined as body mass divided by the square of body height. What is more, people with limited literacy often do not know their true weight and height, which can result in significant item non-response and/or low-quality self-reports of individuals' weight and height [19]. With either one of self-reported weight or height missing, weight for height measures such as BMI cannot be computed at all. The above challenges to obtaining simple and cost-effective, yet reasonably accurate measures of individuals' body size thus call for new easy-to-use and cost-effective survey instruments for measuring body size, which can be readily employed in general-purpose social science surveys, including in resource-poor settings with potentially low levels of literacy, as well as mail, online or mobile device-based surveys that do not allow for in-person measurements.

Originally developed by Stunkard and colleagues [20], silhouette showcards, which depict a series of pictures of distinct body sizes, represent an easy visual tool for measuring perceived body size in general-purpose survey settings. Silhouette showcards display sex-specific body sizes, typically in ascending order of BMI (see Fig. 1) [21]. To measure body size, respondents are asked to pick the picture that best represents their own body size. Besides assessing respondents' own perceived body size, silhouettes have also been used to measure other important concepts in health psychology and nutritional science such as ideal body size for assessing body size dissatisfaction as a potential motivating factor for losing weight through increased exercise or dieting [22–25]. Given the diversity of body sizes by ethnicity, a collection of ethnically-specific silhouette showcards including the original Stunkard silhouettes [20] have been developed and validated as a measure of body size in different populations such as Asians [26, 27], Europeans [28–30], and North and Latin Americans [31–33]. Pulvers and colleagues [21] developed a modified version of these silhouettes based on distinct morphology of African population and used it for body size studies amongst African American population [34–36].

Our study is the first to assess the validity of Pulvers' silhouettes [21] in an adult population in the African

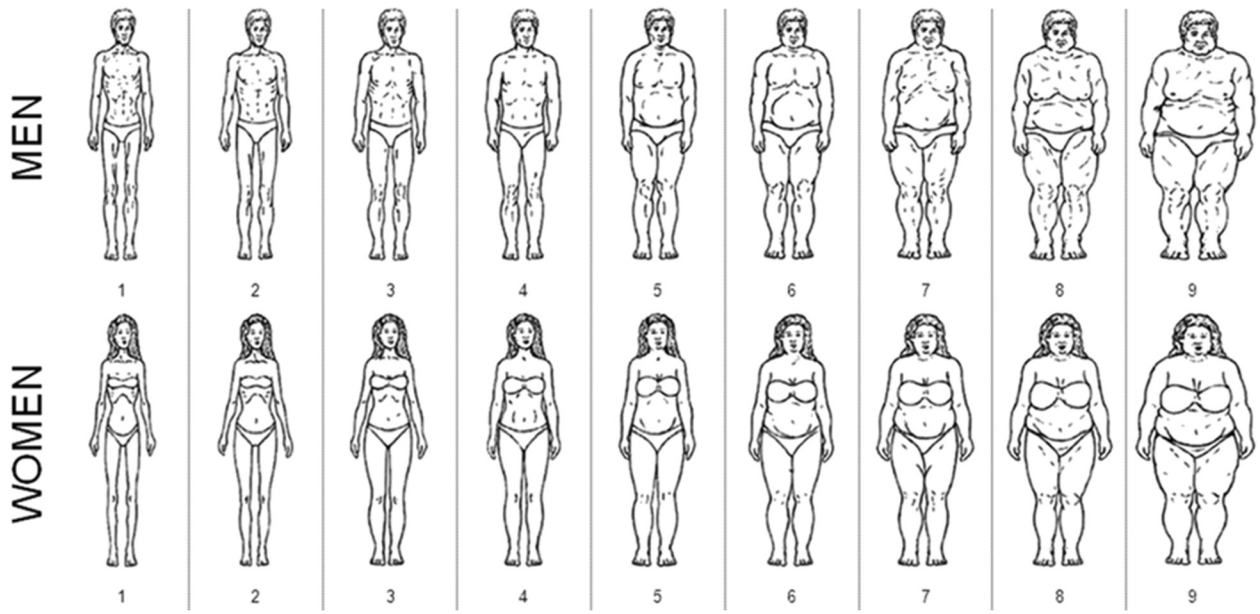

Fig. 1 Pulvers' silhouettes designed for populations of African descent (source: Pulvers 2004, Obesity Res.)

region. Specifically, our study contrasts the self-reported body size obtained from silhouette showcards with comprehensive data from clinical measurements from the Seychelles. This approach allows us to estimate the correlation and the accuracy of showcard-based self-assessments of body-size with a series of clinical indictors of body size and obesity. Our data thus validate the use of silhouette showcards for self-reported body size as a simple, low cost survey instrument for the measurement of body size and obesity in African adults. As a result, our evidence can inform the design of future survey-based assessments of body size and obesity for general-purpose social science surveys, resource-constrained settings or mailed, online, or mobile device-based surveys.

Given their relative simplicity in administration without the need for specialized equipment, training, or respondent knowledge of their weight and height, as well as their low cost in terms of survey time, silhouette showcards could provide a promising tool for cost-effective, reliable measurement of respondents' weight status in general-purpose social science surveys, in which obtaining measured anthropometric data on height and weight data may not be cost-effective or feasible. Similarly, silhouette showcards can be easily integrated into mailed, online, or mobile device-based surveys for which anthropometric measurement is generally infeasible.

Methods

Subjects

We used data from the Seychelles Heart Study IV, a population-based survey conducted in 2013 in the Republic of Seychelles, a group of islands in the Indian Ocean east of Kenya. The Seychelles is a middle-income country and the majority of its population is of African descent. The survey followed the STEPwise approach of the World Health Organisation (WHO) and was approved by the Ministry of Health of the Seychelles following a technical and ethical review [13, 37]. The study sample consisted of 1240 persons aged 25–64 years, randomly selected using sex- and age-stratified sampling based on computerized data of 2010 national population census. Eligible participants were invited by letter to attend the survey and questionnaire and measurements were made by trained survey officers in one main study center in each island. The participation rate of the study was 73 %.

Survey

The survey consisted of two components: (1) a face-to-face interview, which elicited information on respondents' characteristics, including their sociodemographic status and health-related behaviours and outcomes, followed by (2) a health examination comprising a series of anthropometric measurements such as measured height and weight, waist circumference, and body fat percent as well as other health measures. The face-to-face interview survey contained our main outcome measure of interest, the sex- and ethnicity-specific silhouette showcard of Pulvers and colleagues [21]. Specifically, the Pulvers silhouette showcards were based on the body image instrument specifically developed for populations of African descent (Fig. 1) and has shown to have a high inter-rater reliability (Cronbach α =0.95) and

a high correlation with BMI amongst African American population [21]. This nine-image showcard presented sex-specific body sizes ranging from very thin (estimated BMI of 18 or less) to very obese (estimated BMI of 40 or higher). Specifically, perceived body size was measured based on participants' response to the question "In this drawing, which figure best reflects how you think you look with regards to your weight?" and participants' responses were recorded on a scale from one (for the thinnest silhouette) to nine (for the most obese silhouette). Participants were also asked about their current weight in kilograms, if known.

During the interview, information on average monthly earnings in Seychelles rupees (1 US$ ≈ 12 SRP in 2013) was collected. Income data was dichotomised using an 8000 SRP cut-off, representing average monthly earnings of our sample which also corresponded to average population earnings in 2013, according to the Seychelles National Bureau of Statistics [38]. Similarly, information on education was collected based on highest degree completed and dichotomised at the obligatory schooling cut-off, corresponding to the mean educational attainment of the sample. Education groups were those respondents with partial or completed obligatory schooling (zero to 11 years) and those with additional post-obligatory degrees from a polytechnic institute or university.

Anthropometric measurement

We also analysed anthropometric data from the health examination component. Weight was measured with participants wearing light clothing and without shoes, using a calibrated medical electronic scale (Seca). Height was measured using a fixed stadiometer. Body fat percent was measured by the bioelectrical-impedance method (Omron Karada Scan BF504). Waist circumference was measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest, while hip circumference was measured around the widest portion of the buttocks, with the tape parallel to the floor. BMI, waist to hip ratio, and waist to height ratio were calculated and used as body size and adiposity indicators [13].

Statistical analysis

All analyses were performed separately for men and women using STATA SE 12 software (StataCorp, College Station, TX, USA). BMI was calculated as weight in kilograms divided by the square of height in meters. Body weight status was classified as underweight (BMI < 18.5 kg m^{-2}), normal weight (BMI 18.5–24.9 kg m^{-2}), overweight (BMI 25.0–29.9 kg m^{-2}), or obese (BMI > 30.0 kg m^{-2}) using the standard WHO categorization [39]. Box plots, fitted linear regression, and spearman correlations were used to describe associations between silhouette rankings and other body size and adiposity measures.

To evaluate the performance of silhouette rankings in detecting obesity, the BMI greater than or equal to 30.0 was used as the cut-off for obesity status [39]. We employed sex-specific receiver operating characteristic (ROC) analysis to assess silhouettes' predictive validity compared to other body size and adiposity measures. The area under the curve (AUC) was used to compare the performance of silhouette rankings in predicting obesity with AUC of 1.0 indicating perfect discrimination, 0.9 excellent, 0.7 good, and 0.5 or less poor discrimination. Based on sensitivity and specificity estimates obtained from the ROC analyses, positive predictive values (PPV) and negative predictive values (NPV) were calculated to assess the diagnostic value of the silhouette rankings given the different prevalence of obesity in men and women.

To further assess the ability of the silhouettes rankings to detect the social patterning of body size and obesity, we also estimated two separate age-adjusted linear regression models, one using the silhouette rankings and the other with BMI as the outcome measure. The two

Table 1 Sample characteristics by sex (Seychelles, 2013, $N = 1240$)

	Men ($N = 531$)	Women ($N = 709$)
	Mean (SD)	Mean (SD)
Age	46.3 (11.1)	45.2 (11.1)
Measured weight (kg)	79.4 (16.6)	76.3 (17.2)
Measured height (cm)	173.5 (6.6)	1613.3 (6.2)
Self-reported silhouettes (1/9)	4 (1.4)	5.2 (1.6)
Measured BMI (kg m^{-2})	26.4 (5.4)	29.3 (6.4)
Body Fat% (Bio-impedance)	23.2 (8.1)	41.1 (7.9)
Waist circumference (cm)	93 (13)	93.5 (13)
Hip circumference (cm)	102.3 (9.7)	108.7 (11.7)
Waist to height ratio	0.9 (0.1)	0.9 (0.1)
	Prevalence N (%)	Prevalence N (%)
BMI (kg m^{-2})		
Thinness (<18.5)	19 (3.6)	8 (1.1)
Normal (18.5–24.9)	204 (38.4)	172 (24.3)
Overweight (25–29.9)	196 (36.9)	241 (34.0)
Obese (30–60)	112 (21.1)	288 (40.6)
Income (in Seychells Rupees)		
Up to 8000 SR	345 (65.0)	539 (79.0)
More than 8000 SR	186 (35.0)	170 (24.0)
Education		
None or Obligatory	390 (73.4)	474 (66.9)
Polytechnic/University	141 (26.6)	253 (33.1)

Note: Values presented as mean, standard deviation (SD), and prevalence in %

binary socioeconomic predictors used in these models were respondents' income and education level.

Results

The descriptive sample statistics for men and women (Table 1) highlight significant sex differences in body sizes. The mean BMI for women was 29.3 compared to a mean BMI of 26.4 in men ($P < 0.001$). Similarly women had a higher total body fat percent of 41.1 % compared to 23.2 % in men ($P < 0.001$). The self-reported body size ranking based on the nine pictorial silhouettes also reflected similar sex differences in obesity with mean rankings of 4.0 and 5.2 in men and women, respectively (scale from one to nine). A similar proportion of men (65.0 %) and women (76.0 %) earn SR 8000 or less per month (approximately USD $640) and about 70.2 % of the population had obtained partial or complete compulsory school education.

When asked about their weight in kg, 31.5 % of respondents could not provide any information on their weight. The proportion of respondents who did not provide an answer to the weight question was higher in the low-income (52.1 %) and low-education (50.1 %) groups compared to the high-income (15.0 %) and high-education (13.9 %) segments of the population ($p < 0.001$). No significant difference in missing weight information was observed by sex or BMI status. Self-reported height was not included in survey. As a result, sociodemographic differences in self-reported height or BMI cannot be reported here. For those who provided an answer to the weight question, we obtained a discrepancy from −16.6 to +43 kg between measured and self-reported weight. The overall mean difference between measured and self-reported weight is −1.8 kg with no significant difference in under-reporting between women (−2.0, SD 5.35) and men (−1.5, SD 6.87).

For each silhouette category, the box plots in Fig. 2a-d indicate the conditional medians (horizontal lines in the boxes), the 25th and 75th percentiles (lower and upper hinges of the boxes), and lower and upper adjacent values (indicated by the ends of the whiskers in the charts) of the anthropometric measurements within each silhouette category. These box plots indicate that the medians and the 25th and 75th percentiles of the conditional distribution of subjects' anthropometric measurements increased with increasing silhouette rankings for all four anthropometric adiposity measures. Fitting sex-specific linear regression models for each of the four anthropometric measures using the silhouette ranking as an explanatory variable showed a generally good fit overall (all $R^2 > 0.5$). Moreover, the respective fits tend to be slightly better for women than men.

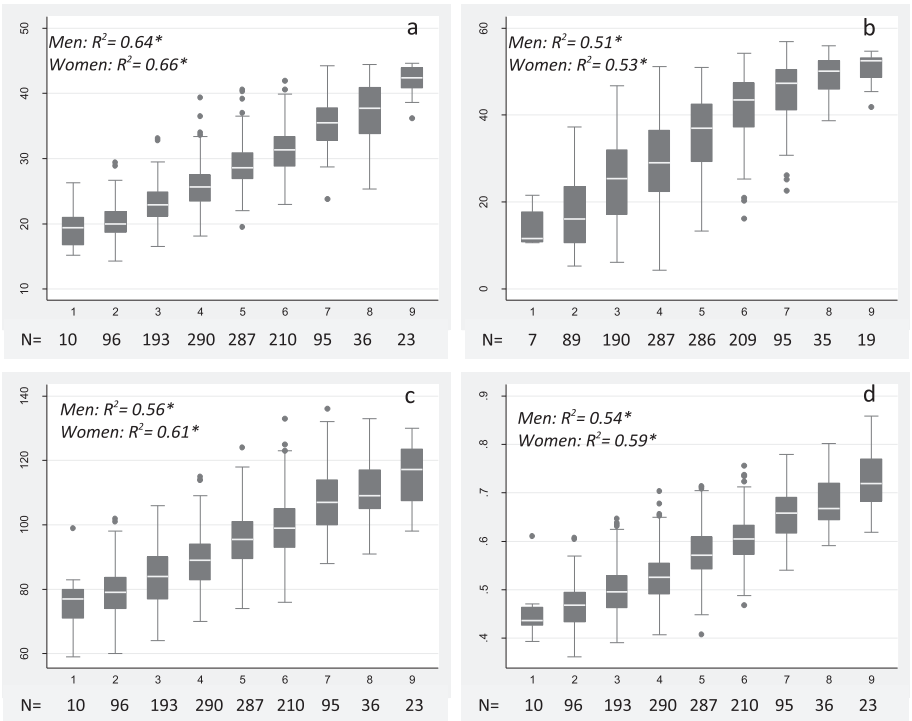

Fig. 2 a-d Box plot relationships between self-reported silhouette ranking and selected adiposity measures (Seychelles, 2013, $N = 1240$). Note: measured BMI (**a**), fat percent (**b**), waist circumference (**c**), and waist to height ratio (**d**). Sex-specific linear regression R-squared values are presented with * when significance at <0.001. Number of participants selecting a given silhouette ranking is specified below each plot

Table 2 Spearman correlation coefficients between self-reported silhouette ranking and selected adiposity measures (Seychelles, 2013, $N = 1240$)

	Men		Women	
	Correlation coefficient	*p*	Correlation coefficient	*p*
Body mass index (kg/m2)	0.80	<0.001	0.81	<0.001
Percentage body fat (%)	0.71	<0.001	0.73	<0.001
Waist circumference (cm)	075	<0.001	0.78	<0.001
Waist-to-height ratio	0.74	<0.001	0.77	<0.001

The Spearman correlation analysis of the relationship between the self-reported silhouette rankings and the other body size and adiposity measures yielded correlations ranging from 0.71–0.81 which are statistically significant in all four cases. The highest correlation coefficient was observed with BMI in men (0.8) and in women (0.81) and the lowest correlation was with body fat percent in men (0.71) and in women (0.73) (Table 2).

The accuracy of the silhouette show cards in detecting obesity (as per the standard cut-off BMI of 30) was analysed using sex-specific ROC analysis (Table 3). The silhouettes had an area under curve (AUC) of 0.91 in men and 0.89 in women. These AUC values were similar to those of waist circumference (AUC of 0.95 in men, and 0.94 in women), fat percent (AUC of 0.94 in men and women), and waist to height ratio (AUC of 0.95 in men and 0.94 in women) for detecting obesity (BMI > 30). The overall discriminatory power of silhouettes to detect obesity was thereby similar in both men and women ($P < 0.001$) (Fig. 3).

Table 4 presents detailed estimates of sensitivity, specificity, and positive and negative predictive values for detecting obesity for each possible silhouette cut-off by sex. As the table shows, commonly proposed cut-offs for detecting obesity (cut-offs five or six) offers reasonable classifications of subjects as obese or not in terms of sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for both men and women.

Table 5 presents some further evidence on the ability of the self-reported silhouette rankings to detect the social patterning of body size. To this end, we compared sex-specific regression models for measured BMI on binary measures of income and education with corresponding models for the silhouette rankings on the same explanatory variables. While the magnitude of the coefficients are not directly comparable across regression models due to the different scales of the two outcome variables (measured BMI and silhouette rankings), we can still compare the regression coefficients' signs, relative sizes, and statistical significance. As Table 5 shows, we obtained similar signs, relative sizes, and patterns of statistical significance for the income and education indicators in the regressions for measured BMI and the silhouette rankings for both men and women, highlighting the ability of the silhouette rankings to detect the socio-economic patterning of body sizes in our study population.

Discussion

Our study is the first validation study of Pulvers' silhouette body size showcard as a simple self-reported survey measure for body size and adiposity in the adult population in the African region. Our findings reveal self-reported silhouette rankings to be comparable to other measured body size and adiposity indicators such as measured BMI, fat percent, waist circumference, and waist to height ratio. ROC analyses for both sexes further highlight the ability of self-reported silhouettes to serve as a good proxy for obesity. In addition, regression analyses show that silhouettes are also able to capture the social patterning of body size. The latter is particularly important in general-purpose social science survey settings, where the social patterning of body size is often of key interest. Our study thus highlights the usefulness of silhouette showcards for face-to-face general-purpose social science surveys when anthropometric measurements may not be feasible or cost-effective. While our study results are based on such face-to-face interviews, our findings also suggest the potential usefulness of silhouette showcards as a tool for assessing body size and obesity in mailed, online, or mobile device-based surveys, even though direct tests of the validity of silhouette showcards in the context of these alternative survey modes should still be conducted.

Table 3 Performance of self-reported silhouette ranking and other adiposity measures in detecting obesity by sex (Seychelles, 2013, $N = 1240$)

	Men ($N = 531$)			Women ($N = 709$)		
	AUC	SE	CI	AUC	SE	CI
Silhouettes	0.91	0.01	0.89–0.93	0.89	0.01	0.87–0.91
Waist circum.	0.95	0.01	0.94–0.97	0.94	0.01	0.92–0.95
Fat percent	0.94	0.01	0.92–0.96	0.94	0.01	0.92–0.96
Waist/Height	0.95	0.01	0.94	0.94	0.01	0.92–0.95

Note: Receiver Operator Characteristic (ROC) analysis resulting in Area Under the Curve (AUC), Standard Error (SE), and 95 % Confidence Interval (CI), for detection of obesity: BMI ≥ 30 kg m^{-2}

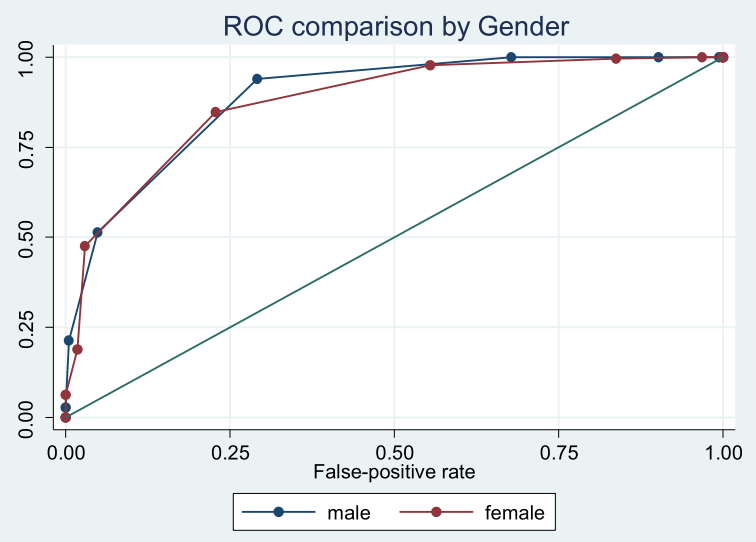

Fig. 3 Performance of silhouettes for detection of obesity in men and women (Seychelles, 2013, *N*=1240). ROC curve to detect obesity (BMI of 30 or higher) using the 9-silhouette body size instrument in men and women

The rate of non-response of self-reported weight is rarely included in studies assessing the accuracy of self-reported weight [40, 41]. Such missing information and its associated factors can reveal important differences between subjects within a population. In our study, the differences between obtained and missing information on self-reported weight amongst various socioeconomic groups show that more than 50 % of people amongst lower education or income groups were not able to provide information on their weight status. This finding underlines the important challenges of collecting self-reported anthropometric data in low- and middle-income populations where obesity is a growing concern and where silhouette showcards can offer a cost-effective alternative to self-reported body size.

In our correlation analysis, we found self-reported silhouette rankings to be highly associated with other anthropometric measures of body size and adiposity such as BMI, waist circumference, waist to height ratio, and fat percent. Using Stunkard silhouettes, Bulik and colleagues [29] found similar Spearman correlations coefficients with BMI in Caucasians (0.73 for men and 0.81 for women) and Nagasaka and colleagues [27] also found correlations of 0.73 in men and 0.80 in women using a Japanese version of body shape silhouettes. The similarities of these different ethnically-specific silhouette showcards with measured BMI further suggest the relatively high degree of validity of showcards for measuring body size across different cultures and ethnicities.

Using BMI of 30 or greater as the cut-off for obesity, the self-reported silhouette rankings show a high accuracy for detecting obesity amongst African adults with AUC values of 0.91 and 0.89 in men and women, respectively. Pulvers and colleagues [36] found similar

Table 4 Discriminatory ability of each self-reported silhouette ranking in detecting obesity by sex (Seychelles, 2013, *N* = 1240)

	Men				Women			
Cut off	Sensivity (%)	Specificity	PPV (%)	NPV (%)	Sensivity (%)	Specificity	PPV (%)	NPV (%)
(=1)	100	0.0	21.0	100	100	0.0	41.1	100
(=2)	100	1.9	21.3	100	100	0.5	41.1	100
(=3)	100	18.4	24.6	100	100	6.9	42.7	100
(=4)	100	45.1	32.6	100	99.3	25.7	48.1	98.5
(=5)	92.0	79.7	54.6	97.4	96.5	56.1	60.4	95.9
(=6)	46.4	97.1	81.2	87.2	80.9	84.1	77.9	86.4
(=7)	18.8	99.8	95.4	82.2	43.4	98.3	94.8	71.4
(=8)	4.5	100	100	79.7	17.4	99.1	92.7	63.3
(=9)	1.8	100	100	79.3	7.3	100	100	60.8

Note: Sensitivity, Specificity, Positive Predictive Value (PPV), and Negative Predictive Value (NPV) of each silhouette ranking in detecting obesity (BMI of 30 or higher) in men and women

Table 5 Age-adjusted regression models for BMI and self-reported silhouette ranking on education and income (Seychelles, 2013, $N = 1240$)

	Men				Women			
	RC	SE	t test	*P* value	RC	SE	t test	*P* value
Measured BMI								
Income	2.44	0.51	4.82	0.00	−0.13	0.64	−0.21	0.84
Education	0.81	0.56	1.44	0.15	−2.46	0.06	−4.1	0.00
Self reported silhouette								
Income	0.62	0.13	4.74	0.00	−0.03	0.16	0.18	0.86
Education	0.22	0.14	1.50	0.14	−0.41	0.15	−2.7	0.01

Note: Comparison of silhouettes with measured BMI in detecting social pattering of obesity in men and women. (RC) Regression coefficients and Standard Error (SE)

AUC in African American participants (AUC 0.88) and assigned the fifth silhouette to best correspond to the classification of overweight and obese individuals (BMI of 25 or higher) in African Americans. According to our ROC analysis, the expected performance in detecting obese subjects at the fifth silhouette reveals the sensitivity and specificity of 92.0 and 79.7 % in men and 96.5 and 56.1 % in women. However, when taking into account the prevalence of obesity, the sixth silhouettes resulted in better PPV and NPV proportions in both men (81.2 and 87.2) and women (77.9 and 86.4).

There are several limitations to our study which need to be considered when interpreting its findings or using it in actual survey design applications. First, while our tool was aimed at a population of African descent, about 10–20 % of our sample was likely from non-African descent (Caucasian, Indian, Chinese). Second, silhouette showcards have only a defined number of images, which tends to limit very thin and very obese individuals in their choice of appropriate images and may therefore not be suitable for those specific populations. Similarly, representing ordered silhouettes from thinnest to heaviest can also results in reporting bias, which suggests that jumbled-ordered cards may be preferred to reduce this potential bias. Third, while there are strong correlations between silhouette rankings and measured anthropometric indicators of body size, each silhouette does not necessarily have a direct correspondence with specific BMI values, which makes it challenging to choose BMI subclassifications, such as measuring overweight status. More accurate BMI-based body size guides have been developed [42] and could be used in future validation studies to further assess the utility of silhouettes as a measure for BMI sub-classification of individuals in survey settings. Finally, our results may somewhat overstate the validity of silhouette showcards as a tool to measure body size given that our survey-based showcard instrument was administered during an in-person face-to-face interview that was followed by a health examination. Our setting may thus have prompted respondents to give more accurate answers on their body size than they would have done otherwise, even though our data still feature considerable misreporting and non-response with regard to respondents' weight and height.

Despite the above limitations, we believe that our study provides new and valuable evidence on the performance of the silhouette showcards for measuring body size and its socioeconomic patterning by comparing silhouette-based outcome measurements with those of four classical anthropometric body size indicators: BMI, waist circumference, waist to hip ratio, and body fat percent.

Our study highlights the validity of silhouettes as a survey tool in a population in the African region. We found silhouettes to be a useful and inexpensive adiposity indicator in population studies when limited resources or other circumstances do not allow for direct anthropometric measurements. The good performance and ease of use of this tool makes it an attractive alternative to measured BMI for general-purpose social science surveys when direct measurement of weight and height is not cost-effective or feasible because of various circumstances, as well as for mail, online, or mobile device-based surveys.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MY was responsible for analysis and interpretation of data, drafting and critical revisions of the manuscript, BV contributed to study conception, design and acquisition of data, PB contributed in study conception, design and data acquisition as well as critical revisions of the manuscript. JM contributed in analysis and interpretation of data, critical revisions of the article as well as supervision of the manuscript content and quality. All authors read and approved the final manuscript.

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Appendix 2

Ideal body size as a mediator for the gender specific association between socioeconomic status and body mass index: Evidence from a low middle income country in the African region

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Ideal Body Size as a Mediator for the Gender-Specific Association Between Socioeconomic Status and Body Mass Index: Evidence From an Upper-Middle–Income Country in the African Region

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Abstract

Background. While obesity continues to rise globally, the associations between body size, gender, and socioeconomic status (SES) seem to vary in different populations, and little is known on the contribution of perceived ideal body size in the social disparity of obesity in African countries. *Purpose*. We examined the gender and socioeconomic patterns of body mass index (BMI) and perceived ideal body size in the Seychelles, a middle-income small island state in the African region. We also assessed the potential role of perceived ideal body size as a mediator for the gender-specific association between SES and BMI. *Method*. A population-based survey of 1,240 adults aged 25 to 64 years conducted in December 2013. Participants' BMI was calculated based on measured weight and height; ideal body size was assessed using a nine-silhouette instrument. Three SES indicators were considered: income, education, and occupation. *Results*. BMI and perceived ideal body size were both higher among men of higher versus lower SES ($p < .001$) but lower among women of higher versus lower SES ($p < .001$), irrespective of the SES indicator used. Multivariate analysis showed a strong and direct association between perceived ideal body size and BMI in both men and women ($p < .001$) and was consistent with a potential mediating role of perceived ideal body size in the gender-specific associations between SES and BMI. *Conclusion*. Our study emphasizes the importance of gender and socioeconomic differences in BMI and ideal body size and suggests that public health interventions that promote perception of healthy weight could help mitigate SES-related disparities in BMI.

Keywords

Africa, body mass index, obesity, perceived ideal body size, silhouette, socioeconomic status

Overweight and obesity are major risk factors for many noncommunicable diseases (NCDs) such as cardiovascular diseases, diabetes, musculoskeletal disorders, and some cancers (World Health Organization, 2015). Since the early 1980s, the global prevalence of obesity has more than doubled, and diabetes currently affects more than 600 million adults. In addition, more than 1.9 billion adults worldwide are overweight (Ng et al., 2013; Salomon et al., 2012). Increasing body mass index (BMI) is a global phenomenon that affects almost all countries irrespective of their level of development (Dinsa, Goryakin, Fumagalli, & Suhrcke, 2012; Finucane et al., 2011). As a result, many developing countries struggle with a so-called "double burden" of diseases, that is, simultaneous challenges stemming from long-standing infectious diseases and undernutrition and increasing NCDs and related risk factors such as obesity and overweight (Lim et al., 2012).

While overweight and obesity continue to rise in low- and middle-income countries (LMICs), there appear to be important differences between high-income countries and LMICs in the association of body size with gender and

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socioeconomic status (SES; Dinsa et al., 2012; McLaren, 2007; Monteiro, Moura, Conde, & Popkin, 2004). First, while overweight and obesity are generally more prevalent among persons with lower SES in high-income countries, the reverse pattern is typically found in low-income countries (Dinsa et al., 2012). Reflecting a reversal in the SES gradient of overweight and obesity as countries develop, middle-income countries often show mixed patterns in the association between SES and body size (McLaren, 2007). Moreover, within-country shifts in overweight and obesity from higher to lower SES groups tend to occur faster and at earlier levels of economic development for women than for men, which suggests important interactions of SES and gender in shaping individual body sizes (Dinsa et al., 2012; McLaren, 2007; Monteiro et al., 2004).

Perceived ideal body size is likely to be an important factor in explaining the observed gender and socioeconomic differences in actual body size (Robinson, Webb, & Butler-Ajibade, 2012; Taylor et al., 1999). Theories in health psychology such as the theory of reasoned action or the theory of planned behavior suggest that health-related attitudes and beliefs at the individual level are important determinants of behavioral intentions, behaviors, and health outcomes (Ajzen, 1991). Similarly, goal setting theory suggests that goals are immediate regulators of behavior. Perceived ideal body size should therefore be an important factor in the development of an action plan that motivates and facilitates the actual adoption of weight control behaviors (Locke & Latham, 2007). At the same time, there is evidence that various social influences affect the level at which individuals set behavioral goals (Bandura, 1991), which may lead to attitudinal differences in perceived ideal body size across gender, cultural contexts, and over time (Biddle, Whitehead, O'Donovan, & Nevill, 2005; Townsend, Takishima-Lacasa, Latner, Grandinetti, & Keawe'aimoku Kaholokula, 2014). Studies have shown that ideal body sizes are strongly influenced by exposure to different cultural contexts and values. For example, identification with some Asian cultures appears to be related to thinner body ideals, whereas identification with African cultures seems to be associated with larger body ideals (Yam, 2013). As a result, differences in perceived ideal body size may explain the changing relationship between gender, SES, and BMI between different cultures, countries of different levels of economic development, as well as cross-cultural and cross-country differences in trends within populations (Dinsa et al., 2012).

Based on data from a population-based survey of adults aged 25 to 64 years, we first describe gender and socioeconomic differences in BMI and perceived ideal body sizes in the Seychelles, a middle-income small island state in the African region. We then assess the potential role of perceived ideal body size as a mediator for the gender-specific association between SES and BMI. Information on the gender and social patterning of obesity and on the potential role of gender and SES-specific attitudes and beliefs on body size ideals can help inform public health weight control programs and policies.

Method

A population-based survey was conducted in 2013 in the Republic of Seychelles, an archipelago of more than a hundred islands located in the Indian Ocean east of Kenya. The Seychelles is an upper middle–income country with a population of 92,000 (World Bank, 2013), and the majority of the population is of African descent. The study is based on a sex- and age-stratified random sample of the adult population aged 25 to 64 years, which was selected from a computerized population registry. The sample consists of 1,240 individuals. The participation rate in the survey was of 73%. The survey was approved by the Health Research and Ethics Committee of the Ministry of Health of the Republic of Seychelles. Additional details on the methods and selected overall findings of the survey have been described elsewhere (Bovet et al., 2007).

Demographic and socioeconomic variables were assessed using a face-to-face structured questionnaire administered by trained personnel. Three indicators of SES were used: income, education, and occupation. These indicators were dichotomized so that the high category includes around one third of participants. Income was considered as high for earnings >8,000 rupees per month (US$1 ≈ 12 rupees in 2013). Education was considered as high for persons who had completed school beyond mandatory school (e.g., technical schools, university, etc.). Respondents' current occupation was dichotomized into manual/nonmanual categories based on the level of qualification required for that position. For example, occupations requiring a professional degree such as teacher, lawyer, and accountant were grouped as nonmanual, while other nonqualified position such as cashier, cook, and farmer were considered as manual. The last held occupation was used for persons who were not currently working in order to account for their level of qualification.

An ethnicity- and gender-specific nine-silhouette scale was used to assess how participants perceived their own ideal body size (Figure 1). The silhouettes are ranked from the thinnest to the heaviest body size and responses are recorded on a scale from 1 (*thinnest*) to 9 (*heaviest*). The underlying instrument was developed based on the Stunkard's silhouettes (Stunkard, 2000) and was validated for use in populations of African descent (Pulvers et al., 2004; Yepes, Viswanathan, Bovet, & Maurer, 2015). To assess respondents' perceived ideal body size, participants were asked, "Which figure best represents how you would like to look with regards to your body weight, ideally?" Weight and height were measured using precision electronic scales

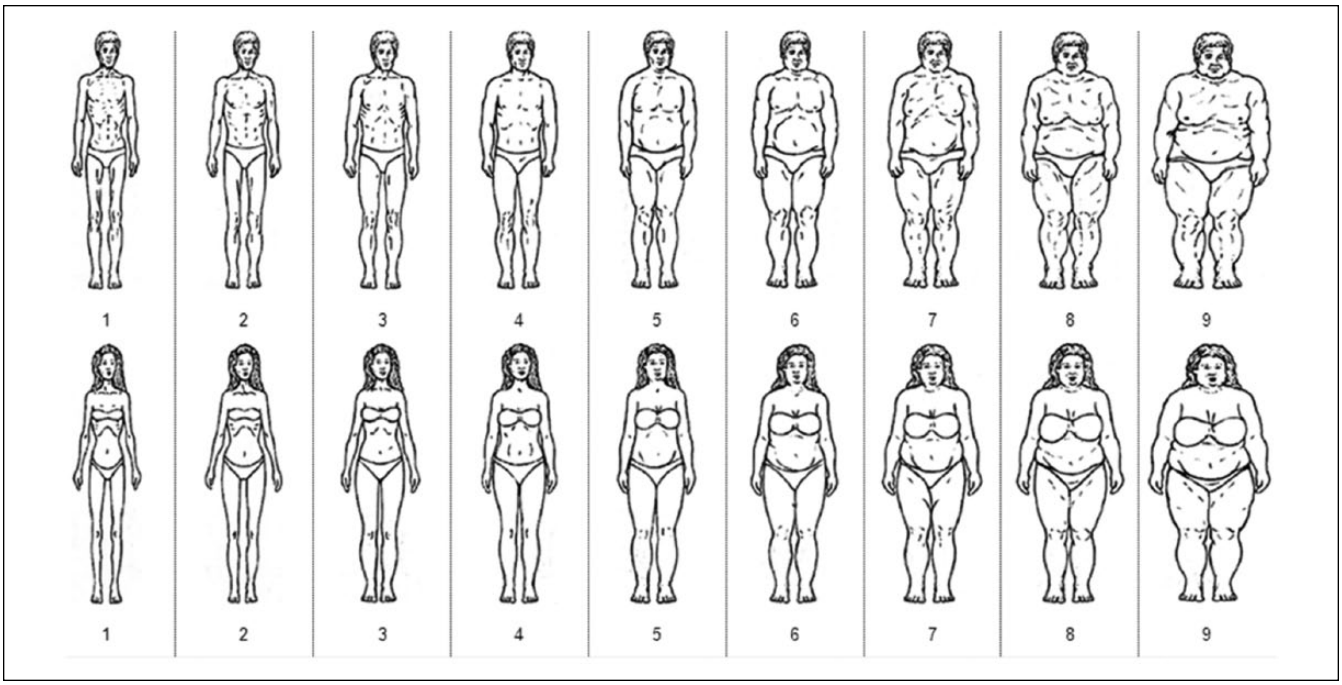

Figure 1. Silhouette scale used to assess perceived ideal body size.
Source. Pulvers et al. (2004).

(Seca™; Hamburg, Germany) and fixed stadiometers (Seca). BMI (kg/m^2) was calculated and respondents categorized as normal weight (BMI < 24.9), overweight (25 ≤ BMI < 29.9), or obese (BMI ≥ 30).

We used cross-tabulations and multivariable regressions to assess gender-specific bivariate and multivariate associations between age, SES, actual body size, and perceived ideal body size. Significance of partial associations between the variables and differences in group means were assessed using the *t* test. Due to relatively high levels of collinearity between the SES indicators, the multivariable regressions included only one SES indicator at a time. Exploratory analysis showed no substantive difference in conceptualizing the silhouettes as cardinal or ordinal variables, and we therefore treated perceived ideal body size as a cardinal variable in the regression analyses of this study. Assuming unidirectional causal pathways from SES to body size, which may be partially mediated by attitudes, beliefs, and goals embodied in ideal body sizes, we used series of linear regressions to show the mediating role of perceived ideal body size in the relationship between SES and BMI. Using structural equation modeling as an alternative to regression analysis resulted in similar findings as linear regressions presented here, and corresponding structural equation modeling results are available on request. All statistical analyses were performed separately for men and women in view of expected differences in the associations between BMI, actual body size, perceived ideal body size, and SES using Stata 12 (StataCorp, College Station, TX).

Results

Table 1 reports descriptive statistics of our study sample as percentages of participants in the following categories: BMI, perceived ideal body size, SES, and age by gender. Table 1 shows 58% of men have an overweight/obese BMI status and 53% of them selected overweight/obese ideal body sizes (silhouettes 4-9). On the other hand, with 74.6% of women in overweight/obese BMI status, 65.7% of them selected the 4 to 9 silhouettes rankings as their ideal body size. Age was similarly distributed among men and women with about half of the sample in each age group (24-44 years and 45-64 years). Two thirds of the sample were in the lower education and income group and one third in the higher SES ranking. Occupation was distributed more evenly in women (52.6% manual, 47.4% nonmanual), while men held more manual position (72.9%) than nonmanual position (27.1%).

Table 2 further demonstrates the opposing socioeconomic differences in both actual body size (i.e., BMI) and perceived ideal body size (i.e., silhouettes) by gender. BMI was lower in women with higher versus lower income, education, or occupation, while BMI was higher in men of higher versus lower income, education, or occupation ($p < .001$). Similarly, ideal body size was lower in women with higher versus lower income, education, or occupation ($p < .001$), while ideal body size was higher in men of higher versus lower income in men ($p < .01$). In men, ideal body size did not differ significantly between categories of higher versus lower education and manual versus nonmanual occupation, respectively.

Table 1. Characteristics of the Study Participants (Seychelles, December 2013, N = 1,240).

Demographics	Men (n = 531), %	Women (n = 709), %
Body mass index		
<25 kg/m^2	42.0	25.4
25-29.9 kg/m^2	36.9	34.0
≥30 kg/m^2	21.1	40.6
Perceived ideal body size		
Silhouettes 1-3	46.3	34.3
Silhouettes 4-9	53.7	65.7
Income (SR)		
<8,000	65.0	76.0
≥8,000	35.0	24.0
Education		
Mandatory	73.5	66.9
Postmandatory	26.6	33.2
Occupation		
Manual	72.9	52.6
Nonmanual	27.1	47.4
Age (years)		
24-44	44.3	48.5
45-64	55.7	51.5

Note. Data presented are percentage of total sample. SR = Seychelles rupees.

Using the classic sequence of regressions for mediation analysis, Table 3 highlights the mediating role of perceived ideal body size in the relationship between SES and BMI. Panel A of Table 3 reports results from gender-specific age-adjusted regressions of BMI on SES using income, education, or occupation as relevant SES indicators, respectively. Adjusting for age, men of higher SES had 1.65 kg/m^2 (occupation) to 2.70 kg/m^2 (income) higher BMI than their lower SES counterparts. Conversely, women of higher SES had 1.55 kg/m^2 (income) to 2.6 kg/m^2 (education) lower BMI compared with women of lower SES. All these differences across SES groups were strongly statistically significant ($p < .001$).

Panel B of Table 3 reports the corresponding age-adjusted multivariable regressions of perceived ideal body size on SES in men and in women. On average, men of higher SES reported 0.35 (occupation) to 0.69 (income) higher mean perceived ideal body size than men of lower SES ($p < .001$). By contrast, women of higher SES tended to report 0.27 (income) to 0.45 (education) lower mean perceived ideal body size than lower SES women, and these partial associations between perceived ideal body sizes and SES were all statistically significant ($p < .05$).

Panel C of Table 3 completes the multivariable analysis and shows the gender-specific age-adjusted regressions of actual BMI on SES and perceived ideal body size in order to explore whether the observed patterns in the data are consistent with perceived ideal body size acting as a potential mediator in the gender-specific SES–BMI relationships. Keeping age and SES fixed, reporting a one unit higher perceived ideal body size was associated with a roughly 3.1 kg/m^2 higher actual body size for both genders. In addition, incorporating perceived ideal body size into a multivariable model for actual BMI led to a significant attenuation of both the positive SES–BMI relationship among men and the negative SES–BMI relationship among women. For men, only income remained statistically significant once perceived ideal body size was incorporated into the model, whereas all three SES indicators were still statistically significant in the regressions among women. We also estimated additional models with SES-perceived ideal body size interactions (results not shown), but the corresponding interactions were generally not statistically significant and the main results above remained largely unchanged.

Discussion

Our findings highlight the mediating role of ideal body size on the relationship between SES and BMI. We found BMI was higher among men of higher versus lower SES ($p < .001$) but lower among women of higher versus lower SES ($p < .001$), irrespective of the SES indicator used. Using mediation analysis, we found a significant positive effect of perceived ideal body size in men ($p < .001$) and a negative effect on women ($p < .001$), suggesting the gender-specific relationship between SES and BMI to be mediated through differences in ideal body size.

The positive association between BMI and SES among men, consistent with previous findings in Seychelles (Stringhini, Viswanathan, Gedeon, Paccaud, & Bovet, 2013) and in some other LMICs (McLaren, 2007), may relate to a cultural perception of males being wage earners, a pursuit of physical dominance and power (McLaren, 2007) or higher perceived prestige conferred by larger body size among men in some countries (Benedict & Benedict, 1982). The negative association between SES and BMI in women in our study is also consistent with previous studies in Seychelles (Bovet, Chiolero, Shamlaye, & Paccaud, 2008; Stringhini et al., 2013) and in some other LMICs (Ball, Mishra, & Crawford, 2002; Bovet et al., 2008; Christine, Diez Roux, Wing, Alazraqui, & Spinelli, 2015; Flynn & Fitzgibbon, 1998; Hammond, 2010; McLaren, 2007; Sobal & Stunkard, 1989; Turrell & Vandevijvere, 2015) but contrasts with data in some countries in the African region, which showed traditional preferences for larger body sizes (Fitzgibbon, Blackman, & Avellone, 2000). Our findings in Seychelles may reflect the adoption of Western values, possibly driven by fast socioeconomic development and increasing exposure to global mass media. The social patterning of BMI observed in Seychelles may not necessarily represent the predominant situation in other countries in the African region but may possibly generalize to other small island states.

There are few studies relating ideal body size and SES in LMICs (McLaren, 2007; Oldham & Robinson, 2015). We

Table 2. Mean Body Mass Index (BMI) and Perceived Ideal Body Size According to Gender and Socioeconomic Status (Seychelles, December 2013, *N* = 1,240).

	Men				Women			
	Perceived ideal body size		Actual body mass index		Perceived ideal body size		Actual body mass index	
Demographics	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
All	3.53	0.04	26.4	0.2	3.96	0.04	29.3	0.2
Income								
<8,000	3.46	0.05	25.5	0.3	4.06	0.05	29.7	0.3
≥8,000	3.66	0.06	28.1	0.4	3.66	0.07	28.1	0.4
	**		***		***		***	
Education								
Mandatory	3.50	0.05	26.0	0.3	4.08	0.05	30.3	0.3
Postmandatory	3.62	0.06	27.5	0.4	3.71	0.06	27.5	0.4
	ns		***		***		***	
Occupation								
Manual	3.52	0.05	25.9	0.3	4.13	0.06	30.5	0.3
Nonmanual	3.56	0.07	27.6	0.4	3.77	0.05	28.1	0.3
	ns		***		***		***	
Age (years)								
24-44	3.60	0.05	26.1	0.3	3.84	0.05	28.6	0.4
45-64	3.48	0.06	26.6	0.3	4.08	0.06	30.0	0.3
	ns		*ns*		**		**	

Note. *SD* = standard deviation.
*$p < .05$. **$p < .01$. ***$p < .001$. *ns*: $p > .05$.

found in this study that gender-specific SES gradients in perceived ideal body size followed the same patterns observed for the association between SES and actual BMI. Our findings support the view that perceived ideal body size can explain, at least in part, the gender-specific relationship between SES and BMI, consistent with psychological theories that emphasize the importance of attitudes, beliefs, and ideals, and the corresponding goals for subsequent outcomes (Ajzen, 1991; Bandura, 1991; Locke & Latham, 2007). An implication of our findings is that interventions that increase the awareness about healthy ideal body sizes might help reduce the prevalence of overweight and obesity and address the corresponding socioeconomic differences in actual body size in the population. Our findings also suggest that perceived ideal body size may be an important determinant of actual BMI.

There are a number of limitations in our study. First, while the gender-specific relationships between SES and BMI in the Seychelles seem comparable to those observed in some other MICs (Dinsa et al., 2012), it is less clear to what extent our results on the potential role of perceived ideal body size as a mediator can generalize to other MICs with different ethnocultural contexts. Second, while our results are consistent with the view that ideal body size may be an important driver of SES differences in BMI, our data are cross-sectional and associations should be interpreted as associations rather than causal links. Specifically, while many psychological theories of health behaviors suggest an important role of attitudes, ideals and corresponding goals toward corresponding health outcomes, there may also be a potential causal connection from BMI in the overall population toward perceived ideal body size if individuals describe their ideal body size in comparison of BMI among their peers. For example, Festinger's social comparison theory posits that individuals continuously compare themselves with their own social groups and tend to minimize discrepancies with them, hence converging their beliefs toward current gender and SES-specific social norms (Festinger, 1954; Smeesters, Mussweiler, & Mandel, 2009). Also, it may be possible that perceived ideal body sizes shift to higher values along the upward secular trends in mean BMI in populations. Hence, while our regression results are consistent with the idea that perceived ideal body size partly mediates gender-specific relationships between SES and BMI, we cannot rule out potential reverse causation. It is likely that both effects play a role and further studies are needed to address the associations between perceived ideal body size, associated factors, and BMI in diverse populations, for example, by assessing these relationships within same populations repeatedly over time, for example, through cohort studies or serial surveys, or by using qualitative study designs.

In conclusion, our data confirm a marked gender and socioeconomic patterning of both BMI and perceived ideal body size in the Seychelles. Our findings are also

Table 3. Mediation of Ideal Body Size in the Relationship Between SES and Body Mass Index for Men (N = 531) and Women (N = 709) (Seychelles, December 2013).

	Income		Education		Occupation		Total	
Panels	RC	*p*	RC	*p*	RC	*p*	RC	*p*
Men								
Panel A								
Actual body mass index								
Income ≥8,000	2.7	***	—	—	—	—	2.37	***
Higher education	—	—	1.78	***	—	—	0.66	*ns*
Nonmanual job	—	—	—	—	1.66	***	0.3	*ns*
Panel B								
Ideal body size (IBS)								
Income ≥8,000	0.19	**	—	—	—	—	0.2	*
Higher education	—	—	0.1	*ns*	—	—	0.06	*ns*
Nonmanual job	—	—	—	—	0.03	*ns*	−0.08	*ns*
Panel C								
Actual body mass index, adjusted for IBS								
Ideal body size	2.08	***	2.17	***	2.19	***	2.01	***
Income ≥8,000	2.3	***	—	—	—	—	1.04	***
Higher education	—	—	1.57	*	—	—	0.54	*ns*
Nonmanual job	—	—	—	—	1.59	*	0.48	*ns*
Women								
Panel A								
Actual body mass index								
Income ≥8,000	−1.55	**	—	—	—	—	0.26	*ns*
Higher education	—	—	−2.61	***	—	—	−1.88	**
Nonmanual job	—	—	—	—	−2.13	**	−1.27	*
Panel B								
Ideal body size								
Income ≥8,000	−0.37	***	—	—	—	—	−0.22	*
Higher education	—	—	−0.3	***	—	—	−0.09	*ns*
Nonmanual job	—	—	—	—	−0.31	***	−0.17	+
Panel C								
Actual body mass index, adjusted for IBS								
Ideal body size	2.68	***	2.6	***	2.61	***	2.6	***
Income ≥8,000	−0.5	*ns*	—	—	—	—	0.85	*ns*
Higher education	—	—	−1.18	***	—	—	−1.64	**
Nonmanual job	—	—	—	—	−1.31	*	−0.82	*ns*

Note. Panels: Age-adjusted regression coefficients of SES indicators on BMI (Panel A) and on ideal body size (Panel B). Panel C reports age and ideal body size adjusted coefficient of SES indicators on BMI. SES = socioeconomic status; RC = linear regression coefficient.
P values (men): *p < .05; **p < .01; ***p < .001; *ns* = not significant.
P values (women): ^{+}p < .1; *p < .05; **p < .01; ***p < .001; *ns* = not significant.

consistent with the views that perceived ideal body size is an important determinant of actual BMI in the general population and in explaining, at least partly, the gender-specific associations between SES and BMI. Public health policies that promote the perception of a healthy weight in selected population groups could help mitigate SES-related disparities in BMI. Further research is needed to increase our understanding of the role of social and psychological factors influencing ideal body sizes and how these factors can be used into weight control programs and policies.

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Part II: Mobile technology

Innovative approaches for health promotion

Introduction

Throughout the 20th century, the developed world experienced a shift in the leading causes of morbidity and mortality from infectious diseases to chronic conditions such as heart disease, stroke, cancer, and diabetes, commonly known as non-communicable diseases (NCDs) [84]. Since then, the medical community has extensively increased its efforts towards prevention of these conditions, and active promotion of healthy behaviours and attitudes. Extensive research on NCD risk factors, have identified behaviours such as tobacco use, diet and physical activity patterns as well as alcohol consumption among the most prominent known contributors to NCD-related mortality [85]. The escalating health care costs associated with NCDs, in addition to epidemiological evidence, and the available technological opportunities have resulted in intensified global commitment to health promotion and NCD prevention.

With the objective of reducing the global burden of obesity and its associated NCDs, WHO has established nine specific targets including 10% relative reduction in harmful use of alcohol and 30% reduction in prevalence of current tobacco use and salt intake, and 10% reduction in prevalence of insufficient physical activity, to name a few [85]. Through numerous multi-sectorial interventions, there has been a dramatic increase in public, private, and professional efforts in screening, disease prevention and health promotion programs. However, more evidence-based health promotion and behaviour change interventions are needed to reduce the global burden of NCD, especially in low middle income countries with limited health care infrastructures.

The growing demand for effective health promotion programs have resulted in increasing research into evaluation and design of evidence-based community health promotion. For example, systematic evaluation of campaigns for prevention of alcohol, tobacco, and other drug abuse [86] exemplify community research methodologies that offer in-depth and valuable insight for development of other programs in diverse settings.

The past two decades have been marked by an increase in randomized controlled trials on design, implementation and evaluation of health education programs. These quantitative and qualitative research findings have resulted in more rigorously studied health behaviour theories at individual and community level and emphasize the importance of carefully planned health promotion interventions based on strong formative and theory-based research [87].

Theoretical approach to health promotion

There are a multitude of evidence-based theories which deconstruct various stages of human behaviour and suggest models for achieving behaviour change such as the health belief model, the theory of reasoned action, the theory of planned behaviour, the transtheoretical mode,l or goal setting theory. These behaviour theories can only be effective when used as an integral part of a comprehensive framework for health promotion interventions. Among the several existing frameworks to guide health behaviour interventions' planning processes, Green and Kreuter's PRECEDE-PROCEED model (PPM) is one that offers clear logical, stepwise and comprehensive roadmap and guidance. Green's PPM identifies 8 steps for applying theories and concepts systematically in the process of assessment, planning and evaluating health promotion strategies [88] (figure 3). This model is based on the simple idea that being healthy or unhealthy are both triggered by numerous individual and environmental factors, and therefore any program that aims to change these behaviours should incorporate all these factors in its design, development, implementation and evaluation. It is similar to the medical model of "diagnosis before treatment" and so the emphasis is on the process of diagnosis which must precede the health promotion intervention, followed by its evaluation [88].

In this model PRECEDE stands for Predisposing, Reinforcing, and Enabling Constructs in Educational/ Environmental Diagnosis and Evaluation of the intervention, and focuses on the process that leads up to an intervention. PROCEED stands for Policy, Regulatory, and Organizational Constructs in Educational and Environmental Development and describes how to proceed with the intervention itself. Together the model proposes eight stages in the planning, implementation and evaluation of a health intervention.

In the first two phases of Precede-Proceed model, the social and epidemiological assessment relies on the evaluation of the risk behaviours, the available resources, required tools and their acceptance among the intended audience. The second phase concentrates on behavioural and ecological assessments focusing on cluster of behavioural determinants and the associated environmental factors needed to achieve behaviour change. In the third phase, a number of behavioural theories may be used to design effective health promotion and disease prevention messages needed to trigger behaviour change. The fourth phase of this model addresses the administrative and policy aspects needed in the implementation of the interventions. The last four phases focus on data collection for the evaluation of the program and its effectiveness in reaching the planned health outcomes and provide insight for program improvement.

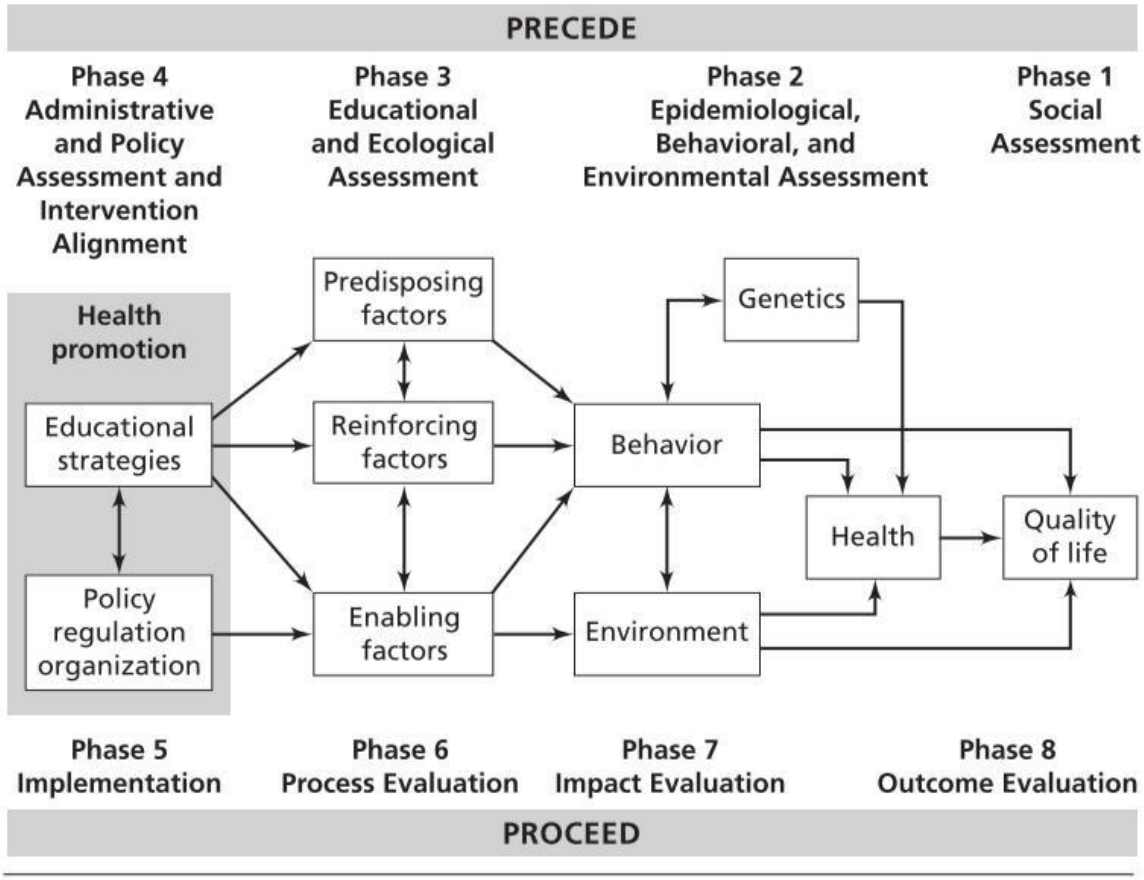

Figure 3. The PRECEDE-PROCEED model. From Green & Kreuter (2005) [88].

The role of technology in behaviour change strategies

There are numerous successful health promotion programs relying on conventional intervention tools such as face to face counselling or group therapy to encourage behaviour change. Due to the limited reach of in-person counselling, the required infrastructure, financial and human resources, there are an increasing number of health programs which incorporate mobile and digital technology for a wider audience reach. The flexibility and customization offered by digital tools as well as their ability to reach a wider audience are increasingly valued by public health professionals in health promotion and research.

Mass media, websites, mobile phones, and smart phone applications offer a unique platform to apply health behaviour theories and address predisposing, enabling and reinforcing components of behaviour change interventions. In recent years, digital technology in health promotion is increasingly adopted due to its flexibility in creating target-specific content, visually-appealing communication interfaces, and timely delivery of educational messages.

Digital technology can serve as a valuable tool in various stages of health intervention as per the Preceed Procede model. Mobile messaging can be used for digital dissemination of heath information to address predisposing determinants of behaviour change, such as information on the benefits of exercise or dangers of smoking. Similarly, mobile and web-based technology can serve in the customisation of enabling features of health interventions such as target-specific and readily accessible information on available health centres, services and other community programs central to sustainable healthy behaviour. Finally, reinforcing factors such as the community attitudes and support can benefit from the adaptability and flexibility offered via digital and mobile technology. For example mobile technology offers the opportunity to belong to a community and connect with members sharing similar health priorities and receiving encouragement from peers.

Digital interventions are a valuable resource at multiple levels of health intervention such as data collection necessary to evaluate and continuously improve health interventions. Advantages of digital/mobile technology in health promotion also includes their potential ability

to reach a much wider audience in a short period of time, as well as the flexibility for designing target specific interventions. In light of growing obesity and NCD epidemic, digital technology is becoming an invaluable tool with the potential to change the prevalence of NCDs for future generations.

Mobile and digital technology in obesity and NCD prevention

Mass media

For the past few decades, public health campaigns have used mass media such as TV and radio to diffuse health-related messages to large audiences. The versatile nature of such media offers a great opportunity for target-specific and emotion-provoking messages on obesity and its associated diseases. In a crowded media environment, it remains difficult to measure the direct impact of mass media campaigns, however, the use of such media in health promotion plays critical role in balancing competing factors such as pervasive product marketing.

Current evidence on health information exposure through mass media indicates that while information is generally passive, mass media can have a positive impact on reducing health-risk behaviour [89]. For example mass media campaigns for anti-smoking have shown to contribute to the reduction in the number of young people starting and increased number of adults stopping smoking [90]. In addition, mass media messages combined with other community programs and tobacco control strategies help reshape the social norms and pave the way for policies which lead to a long term reduction of smoking prevalence [89].

In today's society, the omnipresent channels of information, superimposed with diminishing individual attention may limit the potential effectiveness of mass media in changing individual health behaviour. Consequently, many health promotion campaigns are taking a more target-specific approach with the use of new emerging technologies and resources such as mobile or smart phones.

Mobile health (mHealth)

As a result of rapid mobile technology development, falling market prices and increasing network coverage, there is a ubiquitous rise in mobile phone ownership worldwide. Developing countries are considered as one of the main drivers of global mobile phones growth, as they accounted for 80% of the 660 million new subscription added in 2011 [91]. Today, there are more than 7 billion mobile subscriptions worldwide, up from 738 million in 2000, and internet penetration has increased almost seven-fold from 6.5 to 43 per cent of the global population [92].

The emerging use of mobile and wireless technology in health care, referred to as mobile health or mHealth, has been increasing steadily across all countries worldwide. mHealth has been successfully used in areas such as increasing access to primary care, treatment compliance, health education and promotion as well as in medical response in emergency situations and mobile telemedicine [93].

mHealth's potential in improving health care delivery globally is recognized by world health leaders. During the 2011 United Nation High Level Meeting on NCDs, mHealth was highlighted as a key strategy to combat NCDs in low and middle income countries [1]. In 2012, the "Be He@lthy Be Mobile" initiative, a joint project between WHO and International Telecommunication Union was launched with the aim of using mobile technology, in particular text messaging and mobile applications to help member states combat the growing burden of NCDs [94]. Although it is important to note that success of such programs relies on the reach of mobile technologies across all segments of the population.

Figure 4: ITU-WHO *Mobile Health for Non-Communicable Diseases Initiative*. Source: WHO, 2015

Short message system (SMS)

In recent years, mobile-phone strategies, using either voice telephone messages or short message system (SMS) messages have shown success in providing target-specific health communication programs to encourage specific behaviour changes such as increased fruits and vegetable consumption [95], smoking cessation [96], weight loss [97], and adoption of healthy lifestyle in chronic-disease management [98-100]. Using mobile SMS-based programs, several clinical trials have shown improvement in self-management behaviour and health outcomes in diabetic patients [101, 102]. Interactive voice response and SMS-based interventions for cardiovascular disease management also have shown benefits with respect to hypertension management and hospital re-admissions [103, 104]. A Cochrane review on the SMS-based interventions on smoking cessation found such interventions provide motivation, support and tips for quitting and are effective in helping people to stop smoking [105].

Health promotion interventions using text messaging have the advantage of automation, which facilitate controlled frequency and timing of message delivery. Additionally SMS-based interventions can allow for target-specific messages as well as a two way communication whereby users can respond via encoded messages. For example as part of "Be He@lthy-Be Mobile" program, a two way SMS- based smoking cessation intervention is implemented in Costa Rica, enabling smokers to send a message "crave" when the temptation for smoking peaks. The users then instantly receive an automated response with encouraging messages to help them pass the peak craving phase [106]. Such SMS-based interventions are an efficient delivery channel for providing participants with individually tailored information, feedback, and timely messages.

Despite the generally positive evidence on the benefits of SMS-based interventions, further research is needed to evaluate the added value of mobile technology in reaching health behaviour outcomes in the context of existing behaviour theories and frameworks. Additionally more research is needed to assess the feasibility and effectiveness of mobile-SMS health interventions in low-income, low-literacy settings with high NCD prevalence.

Web-based interventions

According to Barak et al. a web-based intervention is "a primarily self-guided intervention program that is executed by means of a prescriptive online program operated through a website and used by consumers seeking health- and mental-health related assistance" [107]. Numerous studies have examined the effectiveness of web-based interventions and positive outcomes have been reported for smoking cessation [108], weight management [109] and controlled alcohol consumption [110]. Web-based interventions have also been shown to be effective for NCD prevention and management such as in diabetes care [111, 112] and lifestyle modification in a population with metabolic syndrome [113, 114]. Recent studies on the use of web-based platforms for physical activity indicate an added benefit in terms of encouraging physical activity, particularly when the web intervention is in combination with pedometers which can result in increased physical activity and higher adherence to a healthy lifestyle over time [115].

Once evidence-based health content is created online, the advantage of web-based interventions is mainly in their ability to reach a larger number of people; however more research is need on how to create web-based health content, how to reduce attrition from programs and increase repeated visits for effective and sustained behaviour change.

Smartphone application

Since 2007, with the launch of smart phones, there has been an exponential proliferation of apps which have gained the attention of many clinicians and researchers in the health sector. Today there are thousands of health and fitness applications easily available supporting healthy behaviours ranging from exercise, nutrition, sleep and reproductive health.

While there are thousands of health-related mobile applications on the app market (Android and Apple), there are not enough evidence-based structured research on their acceptability and effectiveness in improving health. In a recent review of literature on mobile health apps for

adolescents, authors were unable to find sufficient studies meeting inclusion criteria to conduct a systematic review of the literature [116]. Therefore more studies with larger sample size, in different age groups are needed to determine the potential benefits of mobile applications in health interventions.

Similarly, there is little evidence on the effectiveness of smart phone health applications compared to web- or sms-based intervention for behaviour change due to their limited incorporation in the health promotion and research in recent years. Additionally, mobile applications have inherently a number of advantages due to their interactivity, automatic tracking and personalisation features which makes their comparison with other digital technologies more difficult. Despite the lack of evidence, the use of health applications for targeted behaviour change has promising potential in health promotion programs.

Today's popular health applications have the ability to address one or more determinants of behaviour change, all in one interface. For example, health applications offer predisposing utilities such as providing information, statistics, or benefits of healthy diet, physical activity and dangers of smoking. They can also offer enabling utilities for example geo-locating physical activity centres nearby, tracking calories or other tools needed to enable behaviour change. And finally, health application can incorporate reinforcing utilities by direct interface with social networking sites, encouragement from peers and trainers, coaches or health care providers as well as evaluation and instant feedback based upon the users' self-monitoring.

Various emerging health behaviour theories can be incorporated in the design and development of health applications for a more effective behaviour change and health outcomes [117]. For example, triggers in form of timely decisive information can be used to enable behaviour that matches the level of motivation and ability [117]. Other similar concepts have been applied in health promotion in the form of financial or other incentives [118], policies in form of defaults [119] or environmental components by altering accessibility [120].

Health applications are increasing in popularity due to their accessibility, larger reach, and multiple tailored functionalities. With the availability of abundant variety of health- and fitness-related smartphone applications on the market, such applications have the potential to facilitate healthy behaviour change and contribute to obesity management from a clinical and public health point of view. However there is a lack of evidenced-based health application functionalities or research on their effectiveness in sustained behaviour change. Similarly, there is a lack of official guidelines, policies and recommendations for safety of health applications used for medical purpose. At this point there is only one country with official, yet non-binding recommendations for development of medical- and health-related applications [121], therefore more mHealth-specific research is needed to provide the framework for future policies to ensure quality and safety for users.

Finally, it is important to note that while most health applications are free or very affordable, they require the latest smart phones technology and internet access which limits their reach to high income segments of the population. Therefore with the current disparity in availability of smart phone technology in different socioeconomic groups, health applications remain inaccessible to those in lower income groups which may exacerbate the health inequality caused by digital divide.

Aim of the two mHealth studies

Through two distinct studies, this part of the thesis aims to apply various stages of the Precede Proceed model in the diagnosis, planning and implementation phase, as examples of health promotion intervention using mobile technology. In this part of the thesis, two illustrations of mHealth interventions are evaluated in the context of health promotion and NCD prevention. The first study focuses on the diagnosis (phase 1 & 2) of a potential SMS-based mHealth initiative in a middle income country in Africa (the Seychelles), and the second study focuses on the development and pilot testing (phase 2&3) of a target-specific mobile application to facilitate behaviour change in a high income country (Switzerland).

Paper 3: Diagnosis of mHealth feasibility in Seychelles

Central to the design and implementation of any mHealth strategy is the pre-assessment of available mobile technologies, such as its penetration across different socio economic groups, and its acceptance as a tool for health communication in target communities. Using cross sectional data, the first paper is an example of the pre-assessment and ecological diagnosis phase of Precede-Proceed model whereby the feasibility of a potential health intervention using mobile technology is assessed in the target community. The study starts by exploring mobile technology penetration amongst different socio-demographic and NCD risk groups. Acceptance of mHealth using SMS and email interventions is further examined and compared with current use of mass media such as TV and radio for health information communication.

Paper 4: Development of mobile application

This study develops and testing a mobile health app for nutrition communication in restaurant settings. With increasing number of meals consumed away-from-home, tools enabling informed food choices in restaurants can be an effective strategy against the rise in obesity and NCD. Using a randomised control trial, the study uses menu nutrition labelling as an enabling tool to facilitate healthier food choices. Five different labelling formats are compared with regards to their influence on food choices. The study also serves as a pilot test of a new mobile application as well as a potential research tool in food choice studies.

Summary of findings

Seychelles mHealth feasibility study

A population-based survey was conducted in 2013-2014 in the Seychelles with a randomly selected sample of 1,240 adults, aged between 25-64 years old. The survey consisted of two components, a face-to-face interview, which provided socio-demographic information (age, marital status, income, education and occupation), self-reported health behaviours (physical activity, smoking and alcohol habits), information technology ownership and use (personal

mobile phone, computer, tablet as well as email and internet access). Participants were also asked about their acceptance of receiving health-related email or sms messages as well as exposure to health-related programs on TV or radio. The second part of the survey consisted of a health examination including the assessment of a series of anthropometric measures (weight, height, and waist circumference), clinical measurements and blood analysis (blood pressure and fasting glucose level). Further details on all the variables and measurement criteria are found in Exhibit 1 of this manuscript.

The data highlight 93% mobile ownership with more than 75% penetration amongst all socioeconomic groups. The observed digital divide was most significant with the ownership of smart phone, computer or tablet ownership and well as with internet access. The individuals in upper SES groups were most likely to own personal tablets/computers and use internet on their personal devices. The highest acceptance of mHealth interventions was observed amongst women, younger adults and those in upper SES groups. The was On the other hand, the use of traditional mass media such as radio for health related information showed the highest exposure amongst older adults, or those in the lowest SES groups and remains an important source of health information in these segments of the population. The population with elevated blood sugar or hypertension had high exposure to TV and radio programs on health and were also willing to receive SMS messages related to health.

The findings highlight the need for diverse approaches required when addressing different socioeconomic groups for effective target-specific health campaigns. The complementary reach of mass media with mHealth acceptance suggest the use of selected educational components disseminated via a combination of SMS and mass media for a more comprehensive reach towards NCD prevention for individuals between the ages of 24-65 in Seychelles.

Nutrition labelling on mobile menu app study

This study consisted of 126 participants aged between 20-33 years old with previous use of smart phones or tablet devices, randomly allocated into one of the six nutrition labelling groups

(1 control and 5 labelling formats). A custom-made mobile application was developed for the purpose of this research displaying one of six labelling formats separately. The participants also completed a survey with questions on their lifestyle (physical activity, exercise, reading labels, etc.) as well as their experience with the nutritionally labelled menu app on the iPad (Exhibit 2 of this manuscript). The menu app was designed to provide simple calculation of total calories selected from different categories as a percentage of daily requirements in the form of a horizontal bar graph. This summary was presented to users at the end of their meal selection providing them with the exact calories and colour codes for each item as well the graphic summary (Exhibit 3 of this manuscript).

The findings from this study highlight the utility of a mobile app to compare five different nutrition labelling formats on food choices. The results indicate traffic light colour coding plus a graphic summary as the format with the highest attractiveness, highest perceived influence as well as the lowest average number of calories selected for their meal. The findings also reveal the feasibility of mobile technology to offer nutrition information at point of purchase in restaurants and showed that the use of technology to offer nutrition transparency is highly valued by young adults.

Discussion

Together, the two studies highlighted opportunities and potential limitations of the use of mobile technologies in public health interventions. The pervasive mobile phone penetration and acceptance amongst adult population (between 18-65 years old) emphasize the potential for integration of this technology in health promotion and disease prevention campaigns. However due to prevalent digital divide in mobile ownership and mHealth acceptance amongst those in lower SES and older adults, mobile-based interventions necessitate complementary media such as TV and radio programs for dissemination of health information.

In these two studies, the Precede-Proceed model offered a guiding framework for assessment and planning of behaviour interventions using digital technology. As proposed by the PPM, the first study assessed the feasibility of mobile intervention in developing countries through a detailed diagnosis of mobile phone penetration and mHealth acceptance. The study highlighted the social pattern of information technology ownership and access as well as the complementary role of mass media in planning public health initiative and reaching target groups at risk of NCDs in middle income countries. The second study highlighted the unique advantages of mobile apps to offer predisposing, enabling and reinforcing components of behaviour change, all in a single interface. The availability of nutrition information presented in an appealing format, at point of purchase offers the potential for attractive labelling formats to encourage healthier choices.

The findings from these two studies highlight the potential value but also the numerous limitations of mobile technology in public health campaigns. The growing mobile penetration in all segments of the population allows for more target-specific health messages. However, it is important to carefully assess, plan and design mHealth interventions through collaboration of public health professionals with technology experts and developers. Using existing health behaviour theories and models to develop mHealth promotion interventions can offer more insight of our understanding of the determinants of healthy behaviour.

These two studies offered a glance at digital and mobile technology as a valuable resource in obesity and NCD prevention; however, more evidence-based research on the use of mobile interface is needed for a more scientific approach to development of future mHealth interventions.

Appendix 3

Potential reach of mHealth vs. traditional mass media campaigns for NCD prevention in a middle-income country in Africa

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Original Paper

Potential Reach of mHealth Versus Traditional Mass Media for Prevention of Chronic Diseases: Evidence From a Nationally Representative Survey in a Middle-Income Country in Africa

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Abstract

Background: Public radio and television announcements have a long tradition in public health education. With the global rise of computer and mobile device ownership, short message service (SMS) and email-based health services (mHealth) are promising new tools for health promotion.

Objective: Our objectives were to examine 1) self-reported exposure to programs related to noncommunicable diseases (NCDs) on national public television and radio during the 12 months preceding the survey (2013–2014), 2) current ownership of a mobile phone, smartphone, computer, or tablet, and use of the Internet, and 3) willingness of individuals to receive SMS or emails with information on health, with a focus on distribution of these variables across different demographic, socioeconomic status (SES), and NCD risk groups.

Methods: We obtained data in a population survey of 1240 participants aged 25–64 years conducted in 2013–2014 in the Seychelles, a rapidly developing small island state in the African region. We administered a structured questionnaire and measured NCD risk factors. Univariate and multivariate analyses explored the relationships between outcomes and sociodemographic variables.

Results: Of 1240 participants, 1037 (83.62%) reported exposure to NCD-related programs on public television, while a lower proportion of 740 adults (59.67%), reported exposure via public radio (P <.001). Exposure to NCD-related programs on public television was associated with older age (P <.001) and female sex (P <.001), but not with SES, while exposure to NCD-related programs on public radio was associated with older age (P <.001) and lower SES (P <.001). A total of 1156 (93.22%) owned a mobile phone and ownership was positively associated with female sex (P <.001), younger age (P <.001), and higher SES (P <.001). Only 396 adults (31.93%) owned a smartphone and 244 adults (19.67%) used their smartphone to access the Internet. A total of 1048 adults (84.51%) reported willingness to receive health-related SMS, which was positively associated with female sex (P <.001), younger age (P <.001), and higher SES (P <.001). Controlling for SES, exposure to NCD-related programs on public television or radio and willingness to receive health-related SMS were not independently associated with a person's NCD risk.

Conclusions: Broadcasting health programs through traditional mass media (national public radio and television) reached the majority of the population under study, including older adults and those in lower socioeconomic groups. With a high penetration of mobile phones and willingness to receive health-related SMS, mHealth presents an opportunity for health programs, especially when targeted SMS messages are intended for younger adults and those in higher socioeconomic groups. By contrast, due to reduced Internet access, email-based programs had a more limited reach for health promotion programs. These findings emphasize

the different reach of interventions using SMS or email versus traditional mass media, according to demographic and socioeconomic categories, for health education programs in a developing country.

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KEYWORDS

digital divide; mHealth; eHealth; mass media; mobile phone; noncommunicable diseases; short message service; email; internet access; developing countries; low- and middle-income countries; Africa

Introduction

Evidence suggests that prevention and control of noncommunicable diseases (NCDs) is one of the major health challenges of the 21st century, including in low- and middle-income countries [1,2]. Multifaceted health education strategies combined with multisectoral policies aimed at promoting healthy behaviors are needed to reduce the burden of NCDs [1-4]. Before planning new NCD-related interventions to raise health awareness in the population, it is important to assess the reach of the existing mass media campaigns and to evaluate the potential audience of the planned additional interventions [4]. In this study, we assessed the reach of health education programs on national public television and radio in the Seychelles and the potential reach of short message service (SMS) or email-based interventions (mHealth) according to age, sex, socioeconomic status (SES), and health risk groups.

Health education through traditional mass media such as television and radio, when provided at a sufficiently high frequency, can promote healthy behaviors [5,6]. Advantages of health education campaigns through traditional mass media include a wide audience reach, an easily augmentable frequency of delivery, a high degree of control over content, and a relatively low cost per person exposed [5]. On the other hand, limitations include difficulties in capturing audiences' attention in an increasingly cluttered media environment, the 1-way flow of information from providers to consumers, and a limited ability to offer target-specific messages to pre-identified audiences [6].

To outweigh some of the limitations of health education programs based on traditional mass media, a growing number of SMS or email-based (mHealth) interventions have been used in both developed and developing countries. The steady rise in ownership of mobile phone and other digital communication technologies has facilitated mobile-based interventions, including the provision of health information through mobile messaging and emails [7]. For example, the use of mHealth was highlighted as a key strategy to combat NCDs in developing countries at the 2011 United Nations high-level meeting on NCDs [1]. Pursing this strategy, telecommunication agencies and the World Health Organization (WHO) launched the initiative "Be He@lthy Be Mobile" in 2015, which aims to leverage mobile technology, in particular text messaging and related apps, to help combat the growing global burden of NCDs [8].

In recent decades, there has been a considerable rise in mobile phone ownership in low- and middle-income countries [9]. Based on data from the International Telecommunication Union [9], Figure 1 highlights the growth of mobile phone subscriptions in 48 upper middle-income countries. Figure 1 illustrates that the rate of mobile subscriptions per 100 inhabitants in 50% of upper middle-income countries increased more than 20-fold between 2000 and 2014. The Seychelles—our study site—consistently ranked in the top 25th percentile of upper middle-income countries throughout this period, reaching 160 mobile subscriptions per 100 inhabitants in 2014 [9]. By 2010, the penetration of mobile phones in the Seychelles had surpassed household ownership rates of landline phones (49%), radio (87%), and television (95%) [10].

Mobile-based interventions are increasingly used in health promotion campaigns providing target-specific SMS that encourage specific behavior changes such as increased fruit and vegetable consumption [11], smoking cessation [12], and adoption of healthy lifestyles [13]. Furthermore, mobile-based approaches have also been increasingly applied to address various aspects of disease prevention such as appointment keeping, medication adherence, medical test results delivery, remote diagnosis, data collection, access to health records, disease tracking, and medical response in emergency situations [7,14-18].

SMS- or email-based programs offer several advantages over traditional mass media for health promotion and disease prevention, as they provide opportunities for interactive 2-way communication [15] and target specific, tailored behavior change communication [16,19]. Such interventions offer the opportunity for dissemination of automated, timely, and target-specific messages, which can be designed to complement or mirror in-person counselling [20,21]. For example, messages can offer tailored advice, behavior tracking, goal setting, encouragement, or personal feedback in different stages of behavior change [22-24]. Many theories focus on the need for health messages to offer predisposing, reinforcing, and enabling components of effective health interventions [25]. Several emerging behavior theories suggest that SMS- or email-based interventions can provide timely health messages that can match the level of an individual's motivation and his or her ability to act, and therefore facilitate behavior change [26]. While many studies have shown that mobile phone strategies, using either voice or SMS messaging, can encourage behavior change by increasing patient self-efficacy and assisting in chronic disease management [15,20,24,27-29], further research on SMS-based interventions is required to design effective public health interventions using mobile technology.

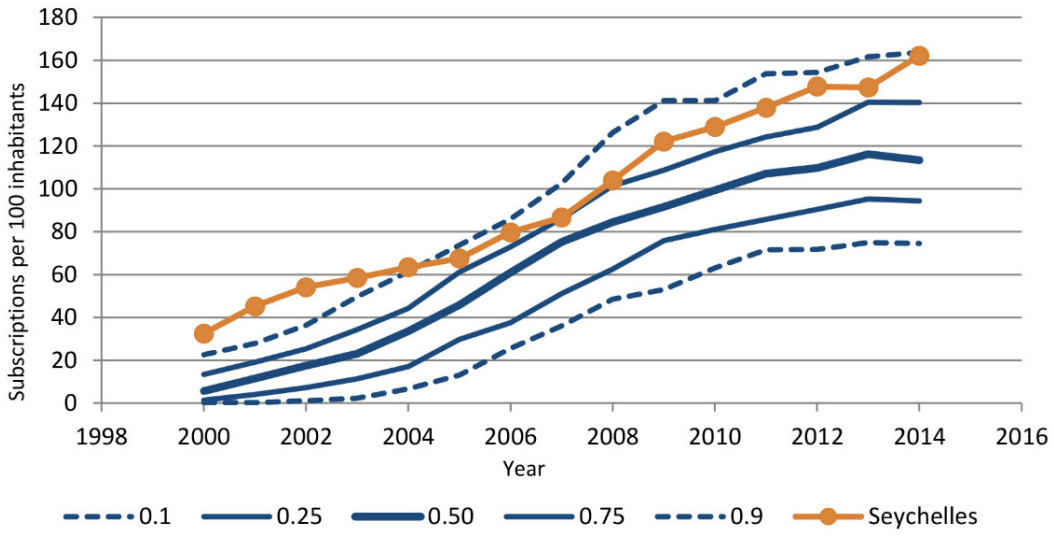
A major constraint in the success of any mHealth initiative is its ability to reach the target population, as well as its adoption, acceptance, and utility from the users' perspective [20,30]. Numerous studies have highlighted the potential inequity in access to technology-based services resulting from differences

in adoption of new technologies such as mobile ownership or Internet access, a concept known as the digital divide [31-33]. Socioeconomic indicators such as sex, education, and income are a few of the many determinants of this digital divide. While the rapid rise in mobile ownership in low- and middle-income countries is reducing the socioeconomic gap in mobile ownership, there remain important differences in adoption of modern technology, particularly in developing countries [31]. Despite this existing gap, several mobile-based initiatives have been successfully implemented in African countries providing health care services to remote areas [24,27-29,34-37].

To date, mHealth interventions in Africa have mostly focused on human immunodeficiency virus/AIDS, malaria, and maternal and child health [20]. However, evidence in support of these approaches in addressing the burden of NCDs in African countries is growing, mainly aimed at improving patient-provider communication [17]. Recent studies have highlighted the benefits of mHealth interventions for cancer care in rural Cameroon [34], Zambia [35], and Nigeria [36] and diabetes care in Western Kenya [37]. However, a continued challenge with health education interventions is to ensure that exposure to health messages extends to all persons targeted, whether a particular group (eg, persons at risk of NCDs) or the entire population, including persons of low SES or otherwise other sociodemographic characteristics that make them less susceptible to be exposed to a particular mass medium.

Despite the overall rise in mobile penetration in developing countries, it is important to assess the penetration of mobile phones and other electronic devices across different demographic, SES, and health risk categories in order to adequately design SMS- or email-based health education interventions. Using data from a national health survey in 2013–2014 in the Seychelles, we assessed 1) self-reported exposure to programs related to NCDs on national public television and radio during the 12 months preceding the survey, 2) current ownership of mobile phones, smartphones, tablets, or computers and Internet access, and 3) willingness of individuals to receive emails or SMS related to information on NCDs, with a focus on the distribution of these variables across different demographic, SES, and NCD risk groups.

Figure 1. Mobile phone subscriptions per 100 inhabitants in percentiles for 48 upper middle-income countries between 2000 and 2014.



Methods

We conducted a nationally representative survey (Seychelles Heart Study IV) in 2013–2014 in the Republic of Seychelles, a rapidly developing small island state in the Indian Ocean, east of Kenya. The survey followed the WHO STEPwise approach to surveillance and was approved by the Ministry of Health of the Seychelles following a technical and ethical review [38,39]. The eligible population included a sex- and age-stratified sample of all adults aged 25-64 years of the 3 main islands, based on computerized data of 2010 national population census, which was thereafter regularly updated by civil authorities. The final study sample consisted of 1240 participants, reflecting a participation rate of 73%.

A structured questionnaire was administered face-to-face by trained survey officers. The questionnaire assessed, among other information, sociodemographic characteristics (age, sex, income, education, and occupation), self-reported health behaviors (including physical activity, smoking, and alcohol habits), exposure to programs related to NCDs on national public television or radio in the past 12 months, ownership and use of selected information and communication technology (mobile phone, computer, tablet, and access to email and Internet), and willingness to receive emails or SMS with information related to health.

Body weight and height were measured and body mass index was calculated as weight (in kg) divided by squared height (in meters). Blood pressure was measured and the average of 3 readings was considered. High blood pressure was defined as blood pressure ≥140/90 mmHg or receiving blood pressure treatment. Elevated blood glucose was defined as plasma glucose >6.1 mmol/L or taking antidiabetic medication. Persons at risk of developing NCD included those who were smoking, drank excessive amounts of alcohol, were not physically active, had high body mass index, or had high blood pressure, high

cholesterol, or diabetes. Multimedia Appendix 1 lists the variables used in this study and their definitions.

We examined the distribution of outcomes across demographic, SES, and NCD risk groups and evaluated group differences using Wald tests. We used logistic regression analysis to assess the associations between socioeconomic variables and our outcome variables (exposure to traditional mass media, ownership of mobile phone and other electronic devices, access to and use of the Internet, and willingness to receive health-related emails and SMS), adjusting for age, sex, and SES. Estimates for crude and adjusted odds ratios were not markedly different and therefore we show only adjusted estimates. Analyses were weighted to reflect the actual population distribution of persons aged 25–64 years. P <.05 was considered significant. Analyses were performed using STATA/SE version 12 software (StataCorp LP).

Results

Table 1 presents the distribution of demographic, SES, and NCD risk categories in the population. Of the 1240 adults, around half had obtained education beyond obligatory education (ie, beyond the age of 15–16 years, and approximately one-third of adults earned more than 8000 Seychelles rupees per month (~US$ 600), in line with data from the Seychelles National Bureau of Statistics [40]. In the sample of 1240 participants aged 25–64 years, the prevalences were 64.32% (n=798) for overweight or obesity, 59.90% (n=743) for hypertension, 21.36% (n=265) for elevated blood glucose, 20.60% (n=255) for smoking, 25.41% (n=315) for heavy alcohol intake, and 23.16% (n=287) for sedentary lifestyle. All proportions are adjusted to the actual age and sex distributions of the population of Seychelles.

Mobile Technology Ownership

Table 2 shows the univariate distribution of ownership of electronic devices and Internet access by sex, age, and SES categories and the multivariate odds ratios for the relationships between the outcomes when adjusted for all the variables displayed in the table. Overall, of the 1240 adults aged 25–64 years, 1156 (93.21%) owned a mobile phone. The distribution differed by sex: 1191 women (96.04%) versus 1120 men (90.32%); age group: 1197 aged 25–34 (96.58%) versus 996 aged 55–64 (80.34%) years; and SES: 1228 persons with university education (99.03%) versus 860 persons who did not complete obligatory school (69.35%). Of the 1240 adults, 396 (31.93%) owned a smartphone, 245 (19.75%) used their smartphone to access the Internet, 678 (54.67%) owned a computer or tablet at home, and 477 (38.46%) had Internet access with a personal computer or tablet. The social patterning of these outcomes was generally comparable with that of mobile phone ownership described above. We observed similar age and SES differences in adjusted models, even if these associations were not always statistically significant.

Exposure to Health Programs on Mass Media

The first 2 columns of Table 3 show the exposure to health programs on NCDs through traditional mass media (limited to health programs from national public radio and television broadcasting company). It is important to note that, in our sample of 1240 adults, 1234 (99.51%) owned a television and 1221 (98.46%) owned a radio. In Table 3 , the reported proportions are univariate, while odds ratios are multivariate, adjusted to other variables. Participants were asked about their exposure to health education programs on national public television or radio on cardiovascular disease, including stroke and heart attack; cardiovascular risk factors such as hypertension, blood cholesterol, or diabetes; and lifestyle habits such as smoking, alcohol drinking, diet, and physical activity. Overall, 1036 of the 1240 participants (83.54%) reported having viewed at least one such program on public television during the past 12 months, while only 740 of the 1240 participants (59.67%) reported having listened to at least one such program on public radio during the same time period.

In multivariate analysis, viewing health-related television programs was higher among women and more mature adults, and there was no clear systematic relationship with SES. Similarly, exposure to health-related programs on public radio was higher among women and older adults, but negatively associated with SES, even though the estimated coefficients were generally not statistically significant.

Willingness to Receive Health Massages by SMS or Email

The last 2 columns of Table 3 present willingness to receive health-related SMS or email messages. For self-reported willingness to receive health-related messages, 1048 of the 1240 (84.51%) participants expressed willingness to receive such information by SMS compared with only 508 participants (40.96%) by email. In univariate analyses, this proportion was significantly associated with female sex: 1096 women (88.39%) versus 1000 men (80.64%); age: 1128 young adults at age 25–34 (90.96%) versus 808 older adults at age 55–64 (65.21%,) years; and SES: 1031 adults with highest (83.14%) versus 634 adults with lowest education categories (51.12%). When adjusted for all explanatory variables at the same time, willingness to receive SMS or emails related to health continued to be positively associated with female sex, younger age, and higher SES, consistent with results of the univariate analyses.

Table 4 examines the proportion of those with NCD risk factors with the likelihood of exposure to NCD-related health programs on national public media and willingness to receive SMS or emails related to health, when unadjusted and adjusted for age, sex, and SES, in addition to all NCD variables. Univariate analysis showed a higher proportion of those with hypertension and diabetes having watched television or radio programs on health in the past 12 months. However, these differences are no longer significant in a multivariate model when adjusted for SES variables. Findings were similar for willingness to receive health-related SMS or email messages. These findings suggest that when individuals' variation in age, sex, income, education, and occupation are taken into account, NCD risk factors (ie, hypertension, elevated blood glucose, overweight, smoking, or high alcohol intake) do not significantly increase or decrease their interest in NCD-related interventions via mass media or mHealth.

Table 1. Characteristics of the study population (Seychelles, N=1240, 2013–2014).

Population characteristics		No.	%
Sociodemographic variables			
Sex			
	Male	621	50.11
	Female	620	49.98
Age (years)			
	25–34	356	28.68
	35–44	362	29.35
	45–54	327	26.36
	55–64	197	15.85
Education			
	Did not complete obligatory	91	7.37
	Completed obligatory	560	45.16
	Vocational	174	14.02
	Polytechnic	344	27.76
	University	72	5.77
Annual income (Seychelles rupees)			
	<3000	106	8.52
	3000–5000	312	25.17
	5000–8000	441	35.53
	8000–15,000	280	22.59
	≥15,000	102	8.20
Occupation			
	Nonqualified laborer	254	20.46
	Semiqualified manual	351	28.28
	Qualified manual	193	15.57
	Semiqualified nonmanual	256	20.64
	Qualified professional	224	18.05
Clinical variables			
Body mass index (kg/m ^{2})			
	<25 (normal weight)	432	34.82
	25–30 (overweight)	424	34.22
	≥30 (obese)	373	30.10
Physical activity			
	Sedentary	287	23.16
	Moderate	780	62.90
	Active	173	13.95
Alcohol consumption			
	None	524	42.22
	Moderate	401	32.37
	Heavy	315	25.41
Smoking status			

Population characteristics		No.	%
	Current smoker	255	20.60
	Ex-smoker	119	9.57
	Never smoked	866	69.84
Hypertension			
	Negative	497	40.10
	Positive	743	59.90
Elevated blood sugar			
	Negative	975	78.66
	Positive	265	21.36

Table 2. Univariate distribution and multivariate odds ratios for ownership of mobile phone, smartphone, computer, or tablet, and Internet access, by sex, age and socioeconomic status (Seychelles, N=1240, 2013–2014).

Population characteristics	Owns a mobile phone		Owns a smartphone		Has access to Internet with smartphone		Owns a personal tablet or computer		Has access to Internet with personal computer or tablet	
	%	aOR[b]	%	aOR	%	aOR	%	aOR	%	aOR
Total	93.2		31.9		19.7		54.3		38.5	
Sex										
Male	90.4	1	28.9	1	18.0	1	51.7	1	38.4	1
Female	96.1	*6.81* [c]	34.9	*1.44*	21.4	*1.49*	56.9	*1.52*	38.6	1.09
P value	<.001		.03		.17		.08		.94	
Age (years)										
25–34	96.6	1	51.8	1	33.7	1	63.6	1	47.8	1
35–44	96.5	0.72	30.8	*0.40*	18.5	*0.43*	62.0	0.93	42.4	0.74
45–54	93.6	0.61	24.8	*0.34*	13.3	*0.33*	49.5	*0.59*	35.1	*0.60*
55–64	80.3	*0.27*	9.90	*0.15*	7.10	*0.22*	31.3	*0.37*	20.1	*0.38*
P value	<.001		<.001		<.001		<.001		<.001	
Education										
Did not complete obligatory	69.4	1	6.10	1	4.70	1	17.4	1	10.1	1
Obligatory	91.8	*1.98*	19.8	1.84	10.00	1.02	38.1	1.31	20.1	0.87
Vocational	95.9	2.54	43.9	*3.85*	28.7	2.48	58.8	*2.66*	30.1	1.82
Polytechnic	99.2	*8.65*	45.8	*3.17*	28.3	2.03	80.0	*3.45*	65.3	2.82
University	99.1	7.70	63.9	*7.42*	51.5	*5.53*	94.5	*6.51*	87.6	*5.64*
P value	<.001		<.001		<.001		<.001		<.001	
Annual income (Seychelles rupees)										
<3000	74.3	1	9.50	1	4.10	1	30.7	1	15.7	1
3000–5000	90.8	*2.62*	26.7	1.87	16.3	2.14	37.0	0.69	20.0	0.61
5000–8000	95.1	*5.45*	30.4	1.95	17.0	1.93	50.4	0.86	34.5	0.89
8000–15,000	98.0	*7.32*	45.1	*2.55*	28.3	2.68	75.0	1.57	59.7	1.45
≥15,000	98.7	*13.8*	41.4	1.93	34.2	*3.45*	92.1	*6.14*	77.9	*3.07*
P value	<.001		<.001		<.001		<.001		<.001	
Occupation										
Nonqualified laborer	83.0	1	13.3	1	5.00	1	22.5	1	6.90	1
Semiqualified manual	93.5	*3.54*	29.6	*1.97*	19.1	*3.31*	43.6	*2.15*	30.2	*4.23*
Qualified manual	92.8	2.25	26.6	1.29	17.7	*2.33*	55.4	*2.47*	34.7	*3.28*
Semiqualified nonmanual	98.6	*4.84*	36.9	*2.14*	22.5	*3.08*	71.0	*4.26*	51.4	*6.72*
Qualified professional	98.4	2.31	54.5	*3.13*	35.4	*3.28*	87.2	*5.53*	75.1	*8.32*
P value	<.001		<.001		<.001		<.001		<.001	

[a]Wald test for univariate differences between the first and last categories of each socioeconomic variable.

[b]Multivariate odds ratios are adjusted (aOR) to all socioeconomic variables (sex, age, education, income, and occupation) with the reference categories identified as 1.

[c]Coefficients with *P* <.05 are represented in italics.

Table 3. Univariate distribution and multivariate odds ratios for exposure to television or radio programs on NCDs during the past 12 months and willingness to receive health-related SMSc or email, by sex, age and socioeconomic status (Seychelles, N=1240, 2013–2014).

Population characteristic	Viewed a program on television		Listened a program on radio		Would like to receive SMS messages		Would like to receive email messages	
	%	aOR[d]	%	aOR	%	aOR	%	aOR
Total	83.6		59.7		84.5		41.0	
Sex								
Male	79.3	1	57.8	1	80.7	1	36.4	1
Female	87.8	*1.92* [e]	61.6	1.08	88.4	*2.73*	45.3	*1.65*
P value	<.001		.2		<.001		.006	
Age (years)								
25–34	70.1	1	43.8	1	91.5	1	49.5	1
35–44	87.2	*2.76*	55.2	1.66	87.1	*0.65*	43.7	*0.61*
45–54	90.0	*3.62*	71.7	3.41	86.3	*0.85*	39.9	*0.54*
55–64	88.9	*3.20*	76.6	3.88	65.2	*0.33*	19.7	*0.26*
P value	<.001		<.001		<.001		<.001	
Education								
Did not complete obligatory	86.0	1	80.0	1	51.1	1	10.3	1
Obligatory	87.1	*1.27*	62.0	0.72	83.0	2.57	21.5	*0.65*
Vocational	74.1	0.84	52.7	0.80	90.1	3.63	32.4	1.04
Polytechnic	81.7	1.09	55.6	0.96	93.4	5.98	67.5	1.56
University	84.7	*1.47*	51.9	0.79	83.2	3.61	93.3	*4.93*
P value	.85		<.001		<.001		<.001	
Annual income (Seychelles rupees)								
<3000	85.5	1	75.7	1	60.1	1	10.0	1
3000–5000	85.3	*1.31*	64.5	0.88	84.5	*2.37*	20.6	*0.92*
5000–8000	82.6	*1.17*	56.7	0.69	87.7	*2.62*	34.7	*1.26*
8000–15,000	82.9	1.22	55.6	0.69	89.3	2.22	63.3	2.29
≥15,000	82.3	0.81	52.0	0.46	83.5	1.99	82.8	5.94
P value	.55		<.001		<.001		<.001	
Occupation								
Nonqualified laborer	85.8	1	72.3	1	69.4	1	3.90	1
Semiqualified manual	83.0	*1.21*	60.2	0.75	88.1	*3.34*	23.6	*5.91*
Qualified manual	77.3	*0.97*	51.3	0.57	82.5	*1.73*	33.7	*6.46*
Semiqualified nonmanual	86.0	*1.06*	54.0	0.55	93.5	*3.08*	59.0	*16.7*
Qualified professional	83.4	0.96	56.7	0.64	87.2	1.30	82.0	25.4
P value	.49		<.001		.001		<.001	

[a]Wald test for univariate differences between the first and last categories of each socioeconomic variable.

[b]NCDs: noncommunicable diseases.

[c]SMS: short message service.

[d]Multivariate odds ratios are adjusted (aOR) to all socioeconomic variables (sex, age, education, income, and occupation) with the reference categories identified as 1.

[e]Coefficients with *P* <.05 are represented in italics.

Table 4. Univariate distribution[a] and multivariate odds ratios for exposure to television or radio programs on NCDs[b] during the past 12 months and willingness to receive health-related SMS[c] or email, by NCD risk factor categories (Seychelles, n=1240, 2013–2014).

Population characteristic	Mobile ownership	Viewed a program on television		Listened a program on radio		Would like to receive SMS messages		Would like to receive email messages	
	%	%	aOR	%	aOR	%	aOR	%	aOR
Smoking									
Smoker	83.3	81.3	1	55.8	1	80.2	1	28.0	1
Ex-smoker	92.2	85.5	0.93	62.6	0.99	84.5	1.31	39.8	1.47
Never smoked	96.2	83.9	0.82	60.4	1.24	85.8	0.87	44.5	0.96
	<.001	.41		.25		.06		<.001	
Alcohol intake									
None	94.5	84.8	1	62.3	1	84.6	1	40.7	1
Moderate	94.8	84.3	1.24	58.6	1.05	85.9	1.13	46.2	0.88
Heavy	89.0	80.3	0.86	56.5	0.91	82.7	0.88	34.5	0.65
.006	.14		.12		.50		0.13		
Physical activity									
Sedentary	93.6	83.9	1	58.6	1	86.4	1	59.0	1
Moderate	93.2	84.8	1.09	60.9	1.03	85.2	0.94	39.8	*0.53* [e]
Active	92.7	77.0	0.81	55.7	0.99	78.3	0.57	19.3	*0.3*
	.72	.11		.58		.05		<.001	
Body mass index									
<25	89.2	82.0	1	53.0	1	83.0	1	38.3	1
25–30	95.7	82.5	0.68	61.1	1.15	84.8	1.01	43.3	0.98
≥ *30*	94.8	86.4	0.7	65.4	1.22	86.0	1.05	41.2	0.98
	.002	.11		<.001		.42		.49	
Hypertension									
Negative	94.9	79.9	1	53.9	1	87.9	1	45.0	1
Positive	90.7	89.0	1.27	68.3	1.05	79.4	0.74	34.8	0.87
	.003	<.001		<.001		<.001		.002	
Elevated sugar									
Negative	94.8	81.8	1	56.7	1	86.9	1	42.5	1
Positive	87.2	90.0	1.36	70.7	1.09	75.8	0.79	34.9	1.23
	<.001	.001		<.001		<.001		.002	

[a]Wald test for univariate differences between the first and last categories of each socioeconomic variable.

[b]NCDs: noncommunicable diseases.

[c]SMS: short message service.

[d]Multivariate odds ratios are adjusted (aOR) to all socioeconomic variables (sex, age, education, income, and occupation) with the reference categories identified as 1.

[e]Coefficients with P <.05 are represented in italics.

Discussion

We found a large exposure to programs related to NCDs on national public television in the adult population aged 25–64 years in the Seychelles. This exposure was especially large among women and older persons, with no significant association with SES. On the other hand, exposure to health programs on radio was lower than on that on television, with higher exposure among persons of lower SES than among higher SES. We found that the majority of adults owned a mobile phone, but fewer owned smartphones, computers, or tablets or had Internet access. The willingness to receive health-related SMS was higher in women, younger adults, and those in higher SES. We also found that willingness to receive health-related SMS was not

independently related to a person's NCD risk. Overall, this study highlights the different reach, according to age, sex, and SES, of health messages on NCDs supplied through public mass media programs versus health messages that would be based on SMS or email. In particular, our findings emphasize the presence of a digital divide according to age, sex, and SES despite the large penetration of mobile phone and other new electronic media in the population. This divide does not mean that modern media are inappropriate for health education programs related to NCDs, but it suggests that interventions based on mobile technology should be carefully designed with regard to specific purposes and audiences. Our findings may have relevance for other countries that are similar to the Seychelles, including other small island developing states or some middle-income countries that have achieved rapid socioeconomic development.

The sociodemographic differences in mobile ownership and willingness to receive health-related SMS or email messages, as found in this study, play a key role in ensuring that mHealth initiatives have an equitable reach among the target populations [30]. While SMS-based interventions have a promising potential for disease prevention and health service delivery, such interventions can also potentially exacerbate health inequalities arising from a digital divide [41]. Our findings are consistent with a social pattern in the uptake of health-related information [42].

In addition to a social digital divide, numerous studies have also suggested a sex divide in mobile technology adoption, with greater mobile access among men than among women in most developing countries [33,43,44]. In contrast, we found that more women than men owned a mobile phone or a smartphone. Women were also more willing to receive health-related SMS and were more likely to watch or listen to NCD-related programs on public television and radio during the year under study. These differences may be small in absolute magnitude but can be important when designing health-related public education programs. This sex difference favoring women over men may be partially explained by the relatively high sex equity in Seychelles, for example, the Seychelles ranked second highest out of 52 African countries for sex equity according to the Ibrahim Index [45].

We also found an age-related digital divide, with modern communication technologies being used more often by younger than by older persons. This age-related digital divide was small for ownership of mobile phones but was larger for smartphone ownership, and access to and use of the Internet. Also, fewer older than younger persons were willing to receive SMS or emails related to health. This is consistent with younger adults and persons of higher SES being prone to adopt new technologies [33,46,47].

We found that persons at higher risk of specific NCD conditions were not more likely to watch or listen to NCD-related public television or radio programs, and were not more willing to receive health-related SMS or emails than were persons at lower NCD risk, when adjusted for demographics and SES. It is possible that persons with NCD risk would have shown more interest in SMS-based health programs if they had been fully aware of the many potential benefits of mHealth in general, such as SMS reminders to attend medical visits or to take medications, or health messages tailored to a person's particular condition.

The finding that the use of mobile communication devices, or willingness to receive health-related SMS or email messages, is higher among younger adults and among persons of higher SES—irrespective of NCD risk—has important public health implications, since NCDs tend to concentrate in persons of older age and in persons of lower SES. The social and age-related digital divides not only stem from different levels of ownership of mobile devices, but also relate to differences in motivation, ability, and skills to use these devices and the related apps. It is likely that the age and socioeconomic digital divides will decrease in the coming generations, which will allow for persons from broader age and SES categories also to benefit from mHealth services. More generally, age, sex, and social differences in the use of mHealth stress the need to carefully design interventions and to address potential equity concerns.

On the other hand, the larger ownership of mobile phones and smartphones, and access to the Internet, as well as the larger acceptance of health-related SMS and emails, among younger adults may be viewed as an advantage when designing SMS-based mHealth initiatives among young adults. In the same line, the frequent use of email and Internet among persons with qualified occupations suggests that this target population could benefit most from Web-based and email health messaging at the work place.

We also found that, despite the overall rise in the use of new media and communication technologies, large proportions of adults continue to listen to and watch health programs on radio and television. This is consistent with a strong commitment from the Seychelles' health authorities to frequently broadcast radio and television programs on health during the past 25 years. We found that exposure to NCD-related programs on television was fairly uniform across age, sex, and SES groups. Hence, these programs may be useful to educate the public about health issues of general interest, such as raising awareness of NCDs in the general public, emphasizing the importance of good medication adherence, explaining the components of a healthy diet, or stressing the importance of regular blood pressure checks. We also found that programs on NCDs on public radio had a larger audience among older persons and among persons of lower SES, which also corresponds to the population subgroups at higher risk of NCD. Hence, there may be some benefit for continued use of traditional media to broadcast health education programs related to NCDs in developing countries such as the Seychelles.

Several limitations of this study need to be highlighted. The age range was limited to 25–64 years, that is, we excluded both children (when healthy behaviors are ingrained) and the elderly (those at higher risk of NCDs). Also, our questions on willingness to receive health-related email or SMS were not designed to assess the whole range of mHealth services. Similarly, questions on exposure to health programs on traditional media did not assess the impact of these programs on behaviors. Finally, while the findings in our study may

possibly extend to a few other rapidly developing small island states or certain upper middle-income countries that have experienced rapid socioeconomic development similar to that in the Seychelles, further research is required to replicate these findings in similar contexts. Strengths of the study include the population-based design, the fairly large sample size, and the assessment of numerous variables related to the use of mobile technology and to the exposure to health programs related to NCDs.

In conclusion, our study offers new evidence on exposure of health-related programs through traditional media and the feasibility and acceptance of mHealth interventions in an upper middle-income country. With a high reach among all groups of the population, national television programs on health appeared to continue to serve as a valuable medium for health promotion and NCD prevention. A large majority of the population owned a mobile phone and were willing to receive health-related SMS messages. However, due to heterogeneous distribution of mobile technology and a digital divide at the time of the survey, mHealth intervention showed the highest potential reach among persons with higher income and education, as well as in younger adults. These finding are important to design and implement mHealth interventions or health programs in the mass media. More generally, this study highlights advantages and disadvantages of traditional mass media versus modern mobile technology for providing health education and the substantial differences in exposure that can occur according to age, sex, and SES. Our findings further emphasize that health education interventions supplied through traditional mass media or through modern mobile technology must be carefully designed in terms of the intended targeted audiences.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Study survey questions and response categories.

[PDF File (Adobe PDF File), 159KB - jmir_v18i5e114_app1.pdf]

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Abbreviations

NCD: Noncommunicable disease
SES: socioeconomic status
SMS: short message service
WHO: World Health Organization

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Appendix 4

Mobile tablet menus: Attractiveness and impact of nutrition labelling formats on millennial food choices

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Article

Mobile Tablet Menus: Attractiveness and Impact of Nutrition Labeling Formats on Millennials' Food Choices

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Abstract

Using mobile tablet technology, this study compared menu selections by millennial-age respondents to test the effects of five different menu nutrition labeling formats for attractiveness, perceived influence, and actual influence on the students' food choices. Labeling formats presented on an iPad involved combinations of numeric caloric values, traffic-light color coding, and percentage of daily intake presented as a graphic summary. Each participant was asked to select four courses from a fine-dining restaurant menu, and each was shown one of the five nutrition labeling formats (or no information at all). Although there was no significant difference in the calorie count for the six groups, the labeling format with traffic-light color coding combined with a graphic summary of the meal's calorie count (compared with the daily recommended intake) received the highest attractiveness ranking. This attractive graphic format also showed a significant positive correlation to its perceived influence on food choices. Overall, participants in all labeling groups indicated a strong support for inclusion of nutrition information on restaurant menus using mobile tablet technology.

Keywords

menu nutrition labeling; calories; traffic-light color system; food choice; mobile tablet technology

Tablet Menu in Hospitality

The food and beverage industry is expanding its use of mobile technology for queue management, reservations, digital menus, kiosk-based ordering, and payment, among other purposes (Dixon, Kimes, and Verma 2009). Considering this steady evolution of technology, the study described in this article examined restaurant guests' reactions to presentations of nutrition and calorie information in several different formats, as part of the ordering process in fine-dining restaurant. The respondents, who are college students (often termed *millennials*), highly valued the detailed graphic presentation of nutrition information on tablet menus, which is not possible using regular paper menus. As explained here, my findings suggest that the use of mobile technology to provide detailed nutrition information on menus is an attractive tool for food and beverage professionals seeking to increase customer satisfaction.

One technology that is growing in popularity for restaurants is the iPad menu, which was used in a hotel restaurant in Australia as early as 2010 (Simpson 2010). The National Restaurant Association's annual "What's Hot" culinary forecast based on a 2012 survey of more than 1,800 professional chefs and nearly 200 professional bartenders reported that 27 percent of participants agreed that tablet computers for menus and wine lists would be among the hottest technology trends in restaurants for 2013 (National Restaurant Association 2012).

Despite the increasing use of digital menus in the restaurant industry, this tool has not yet been studied for its use in menu labeling. Digital menus on mobile tablets offer an excellent research tool, as they can be designed to include a number of different labeling formats, with the potential to include graphic representation of nutrition information on menus. This study is the first of which I am aware to analyze the impact of menu nutrition labeling on clients' food choices using tablet technology.

Menu Nutrition Labeling

The restaurant industry has been the target of recent regulations intended to reduce obesity by providing relevant nutrition information at the point of purchase as a tool to encourage healthier food choices (U.S. Food and Drug Administration [FDA], April 6, 2011). Despite the expense

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of these menu nutrition labeling requirements (Almanza, Nelson, and Chai 1997), the impact of nutrition labeling on consumers' food choices has yet to be conclusively established (Swartz, Braxton, and Viera 2011). Studies in quick service restaurants (QSR) have shown no significant impact of posting calorie counts for menu items. For example, a before-and-after study of King County's (Washington, United States) implementation of menu labeling in a chain restaurant showed no effect on diners' purchases based on calorie content (Finkelstein et al. 2011). Similarly another QSR study indicated that menu labeling may have a positive effect on what parents order for their young children but not for themselves (Tandon et al. 2010). Based on a systematic review of menu labeling research conducted since 2008, Swartz and colleagues found that only two of seven studies reported a statistically significant reduction in calories purchased among consumers using a calorie-labeled menu (Swartz, Braxton, and Viera 2011). These findings suggest an inconclusive impact of calorie labeling in encouraging healthier food choices or decreasing calorie consumption in QSR restaurant settings.

Insights from literature on nutrition labeling on packaged food products suggest that the effectiveness of nutrition labels on consumer decision processes lies in their ability to provide the appropriate nutrition information to specific consumer segments (Caswell and Padberg 1992). It is also believed that labels are likely to be effective when they address specific informational needs and make sense to their target audience (Verbeke 2005). Similarly, menu labeling studies have shown a strong association between the target audience and the effectiveness of nutrition labeling on consumers' food choice. In that regard, a QSR menu calorie labeling study found a decrease in calories selected only on the part of non-overweight individuals (Wisdom, Downs, and Loewenstein 2010), suggesting the effectiveness of calorie information for those actively seeking it. Similarly, a study in a fine-dining setting found that menu calorie labeling was most valued by health conscious and older consumers and was effective in reducing their calorie consumption (Fotouhinia Yepes 2011).

The FDA's (April 6, 2011) menu labeling regulations suggest calorie information as the recommended nutrition labeling format on menus for all chain restaurants, despite the failure of research to show any effect of calorie labeling on food choices (Swartz, Braxton, and Viera 2011). One hopeful development, however, was a recent review study on front-of-package food labels which suggested that a "traffic light" labeling system was most effective in helping consumers identify healthier products, with red, green, and amber traffic-light symbols to indicate fat, saturated fat, sugar, and salt levels according to recommendations (Hawley et al. 2013). These findings suggest that before FDA recommendations for the restaurant industry are formally established and implemented, further research is needed on the effectiveness of different labeling formats on restaurant menus.

The impact of a traffic-light format has been supported by findings from menu labeling studies, in which researchers coded food and beverages in a cafeteria with traffic-light colors and observed increased sales of green-coded items and decreased sales of red-coded items (Thorndike et al. 2012). In another experimental study of different menu labeling formats (using various combinations of kilojoule, percentage daily intake, and traffic-light labeling), respondents most commonly reported using traffic-light labels in making their selections. The groups with traffic-light labeling information selected meals with a significantly lower mean energy content, which constituted a reduction of around 500 kJ (120 kcal; Morley et al. 2013).

Similarly in an online survey study (Liu et al. 2012), four different labels were used (no calorie labels, rank-ordered calorie levels, and red and green circles indicating higher and lower calorie choices). Participants presented with a rank-ordered calorie listing and those shown the colored circles ordered items with fewer calories than those in the no-labels group. The results of these studies suggest that presenting calorie information in attractive and useful formats may increase effectiveness of menu labeling (Liu et al. 2012; Thorndike et al. 2012).

Looking at the meta-analysis by Swart and colleagues, most studies involved a limited number of food categories, as typically found on QSR menus (Swartz, Braxton, and Viera 2011). Similarly, - several studies in quick service settings have indicated that not all consumers or participants were aware of calorie labels due to the speedy QSR ordering process (Finkelstein et al. 2011). In contrast, there have only been a few studies looking at full-service restaurants with many categories of dishes (Pulos 2010; Yepes 2011; Yepes 2013; Josiam and Foster 2009). Studies of full-service restaurants would address the speed of ordering issue by offering more time for food selection and the processing of available nutrition information, as well as allowing guests more food tradeoffs.

Despite all these menu nutrition labeling studies, I believe it is still not clear which nutrition labeling formats are clearest to consumers, which ones actually inspire them to value nutrition more highly, which ones have the power to be the most effective, and why. Such information would be useful for companies that wish to offer such information and for agencies developing nutrition labeling regulations. For these reasons, I offer the study described in this article, which assesses the effects of various labeling approaches for a particularly significant group of consumers—college-age students, often called millennials.

Research Objectives

The use of technology such as digital boards and tablet menus in restaurants offers opportunities for this versatile

technology to serve as a research tool for a better understanding of menu nutrition labeling formats and their impact on consumer food choices. Tablets can be used to present nutrition information in graphic and animated formats and in ways that are not possible with traditional paper menus. This research tool can provide more insight into the effectiveness of different menu labeling formats for restaurants.

Using tablet technology for menu presentation, this research aims to explore the attractiveness and perceived influence of different menu labeling formats, while determining the real influence of each labeling format on food choice using total calories selected by participants viewing different formats. The general acceptability of tablet technology as a restaurant menu is also examined on a group of millennial respondents.

Method

Study Population

The millennial generation or generation Y is generally defined as the generation born between the early 1980s and the early 2000s, roughly 1982 through 2004 (Howe and Strauss 2000; Pew Research Center 2010). Both due to the size of the cohort and their sophistication, they are considered to be an important market segment (Lodes and Buff 2009). They have been characterized as being optimistic, confident, and opinionated decision makers, particularly in areas of trends, style, and innovations (Pew Research Center 2010). The millennial generation is an important area for research particularly related to its reaction to brand loyalty (Lodes and Buff 2009) and introduction of technology in areas such as hospitality.

This study's respondents constituted a convenience sample of undergraduate and graduate students in Switzerland's Ecole Hôtelière de Lausanne. All participants had either owned or used a smart phone or tablet, all had regular exposure to a full-service, fine-dining restaurant as part of their practical training in hospitality management, and they themselves represent on average a third of weekday lunch clients at the on-campus fine-dining restaurant (Fotouhinia Yepes 2013).

Data Collection

To recruit respondents for this study, an e-mail invitation was sent to all students on campus and posted multiple announcements on the school's home page and in the student e-newsletters. Participation was encouraged using a draw for a chance to win lunch for two (valued at 120 Swiss francs, or about US$135) at a full-service restaurant in the region. A total of 126 students registered for participation, with a slightly higher proportion of female participants.

The study design included six experimental groups (one control and five treatment conditions). The participants were randomly allocated into each group according to the order in which they registered to participate in the study (i.e., the first woman to sign up was assigned to group 1, second woman to group 2, and so on), until all participants were distributed equally to each of the six groups of twenty-one subjects, each with eight men and thirteen women.

To reduce bias among the menu treatments, the participants were told the purpose of the research was to test the feasibility of using tablet menus in restaurants, with no mention of the nutrition labeling aspects of the study. Each participant was given an individual 15-minute appointment in a meeting room for the completion of menu food selection on an iPad in the presence of a research assistant. The menu in question was that of the restaurant which was used as the prize. The students were asked to make their food selection as if they had won the prize meal. All participants saw the same menu, but the survey question wording was adjusted to be specific to the menu labeling format received by each participant. Following the completion of their food selection process on the iPad, the respondents were asked to complete an online questionnaire on a separate computer.

To control for other factors such as cost, we presented a four-course prix fixe menu that included six choices for each of four courses (appetizer, main, side, and dessert). Each group had an equal number of red, amber, or green options. The individual meetings allowed for the elimination of any possible peer influence on participants' food selection.

Research Instrument

Taking advantage of the iPad's capabilities, this study included the novel approach of providing an instant calculation of total selected calories for the four dishes the students had selected, with a graphic summary presenting the total calories as percentage of average daily calorie requirements. This was in addition to calorie labeling and traffic-light color coding (Liu et al. 2012; Thorndike et al. 2012). Thus, this study included the following five combinations of these three labeling formats (in addition to the control group who saw no nutrition info): (1) calories alone, (2) calorie + graphic summary, (3) traffic-light color codes alone, (4) traffic-light color codes + graphic summary, and (5) traffic-light color codes + calories.

The nutrition information for the twenty-four dishes on this menu was calculated using the United States Department of Agriculture's (USDA) nutrient database for each ingredient, which allowed for the calculation of the calorie information of each menu item. The dishes' calorie content ranged from 281 to 506 for starters, 422 to 759 for the main dish, 141 to 358 for side dishes, and 211 to 410 for desserts.

Thus, total calories for the four-course meal ranged from 1,005 to 2,033 calories (Exhibit 1).

To present the color-coded calorie information, the USDA reference for the average daily calorie intake was used, which is represented as 2,500 for a man and 2,000 for a woman. The lunch portion of this average daily intake is 40 percent, or 1,000 calories. The meal's calories were divided between starter (25%), main plus side dish (50%), and dessert (25%). The calories of each dish were used to allocate the appropriate color coding, as follows: items with calories in the upper 30th percentile were red, middle 30th percentile were amber, and the bottom percentiles were green for each dish category. Each of the four courses had an equal number of red, amber, and green options per category to allow an equal chance for each item in a particular calorie range to be selected.

The students entered their selections into an iPad using custom-made applications to allow for different labeling groups. Participants in groups with a graphic summary labeling format saw calculation of total calories they had selected from different categories as a percentage of average adult's daily requirements. This summary was presented at the end of their meal selection with the exact calories as well the color-coded graphic summary (Exhibit 1b).

Questionnaire

The questionnaire was developed to include assessment of moderating and dependent variables in addition to calculated calories (independent variable). All items were measured using a 5-point Likert-type scale, from 1 = *strongly disagree* to 5 = *strongly agree*, except for the demographic questions. The questionnaire was tested on a sample of thirty students and staff prior to use in the study.

The first part of the questionnaire included several demographic questions on age, nationality, alcoholic drinks, and exercise habits. To allow for analysis of any possible association between Body Mass Index (BMI) and calories selected, participants' weight and height were recorded as part of demographic questions. The self-reported height and weight were used in the formula $\frac{Weight(\text{kg})}{Height^2(\text{m})}$ for BMI calculation.

The second part of the questionnaire looked into participants' overall experience with the iPad including previous experience, the interface in the study, and the attractiveness of the labeling format presented, as well as its perceived influence on menu selection process. The final part of the questionnaire dealt with the measures of health consciousness variables, using questions adopted from existing scales (Fotouhinia Yepes 2011; Furham 1994; Gallicano and Van Rheede 2010). Health consciousness questions included areas such as concern toward personal weight and calorie consumption, reading of nutrition labels, and seeking nutrition information. The selection of these specific health consciousness factors was derived from the extensive literature review (Divine and Lepisto 2005; Fen 2009; Moorman and Matulich 1993) suggesting the importance the health motivations in use of nutrition labels. Some minor modifications and rephrasing were made so that the questionnaire could be more suitable for this study's context (Exhibit 2).

Data Analysis

Exploratory factor analyses were conducted on survey responses using principal components analysis (PCA) with an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated principal components. PCA was selected since some of the survey questions were being used for a first time in this study, and PCA is sensitive to the relative scaling of original variables (Field 2009). Transformation was conducted using a varimax rotation and the number of factors to extract was determined by the Kaiser criterion (Kaiser 1958), with an Eigenvalue above one. Correlation analysis was done using Pearson correlation. Bonferroni correction method was applied to control for the family-wise Type I and Type II errors arising from multiple analysis of variance (ANOVA) comparisons. The internal consistency of survey questions were tested using Cronbach's alpha reliability test.

Results

Participants

Sixty-two percent of the 126 participants who took part in this study were women. Respondents' mean age was 22.7 years (SD = 2.615, variance = 6.837), with a range of 18 to 33 years. Ninety percent of respondents were age 26 or younger. Self-reported nationalities of participants showed 73 percent European, 16 percent Asian, and 11 percent American. The BMI range varied between 18 and 30 with mean BMI of 21.9 (SD = 2.44, variance = 5.59). Ninety percent had a healthy BMI of 24.70 or less.

Internal Consistency

In the analysis for internal consistency of survey questions, a good reliability was obtained within test scores for selected health consciousness questions (α = .86), perceived attractiveness (α = .79), and perceived influence (α = .87).

Because studies have suggested a positive association between health consciousness and the use of nutrition labels (Grunert and Wills 2007; Hieke and Taylor 2012; Miller and Cassady 2012), I sought to control for this possible confounding variable by testing the homogeneity of the sample in terms of their health consciousness with a one-way ANOVA using the average responses to all health questions

Exhibit 1:

Sample Menu: (a) Study Menu with Calories and Color Coding for Each Item with (b) an Example of iPad Menu Label with Traffic-Light and Graphic Summary.

FORSTARTERS	Calorie	Color
Pan-fried duck liver with smoked breast of duck with beetroot carpaccio	295	Green
Chef's tart with blue cheese, onion jam and dried bacon, lamb's lettuce, blackcurrant vinaigrette	500	Red
Marinated salmon with dill, cauliflower and capers	281	Green
Salad "Hiver 2011" with belperknolle cheese and marinated warm mushrooms	389	Yellow
Sauteed shrimp with red curry, lime and coconut	506	Red
Frothy leek and potato soup flavored with truffle	394	Yellow
MAINCOURSES		
Arctic char fillet poach at 45° C, celery and app le purée, hazelnut crumble	422	Green
Pan-fried perch fillets confit lemon and parsley, artichokes and beans ragout	754	Red
Confit duck thigh, red cabbage with chestnuts and caramelized apple	625	Yellow
Braised beef stew with red wine, sautéed mushrooms, onion and parsley	759	Red
Chicken breast with rosemary, carrots, green cabbage with ginger and honey	438	Green
Barley risotto and dried tomatoes, rocket salad with olives and blue cheese	609	Yellow
SIDEORDERS		
Mashed potatoes	213	Yellow
Creamy polenta with Parmesan cheese	321	Red
Basmati rice	141	Green
Tagliatelli with olive oil and rosemary	200	Yellow
Steamed "charlotte" potatoes	155	Green
French Fries	358	Red
DESSERTS		
Seasonal fruits tart	220	Green
"Quo Vadis" tart with walnut short paste, walnut, roasted pear cream and pear flan	410	Red
Tapioca coconut cream and pineapple mousse	211	Green
Dark chocolate delight with a gingerbread heart	354	Yellow
Pistachio mousse and cherry jelly	315	Yellow
Milk chocolate cake, peanut toffee and mandarin jelly	405	Red

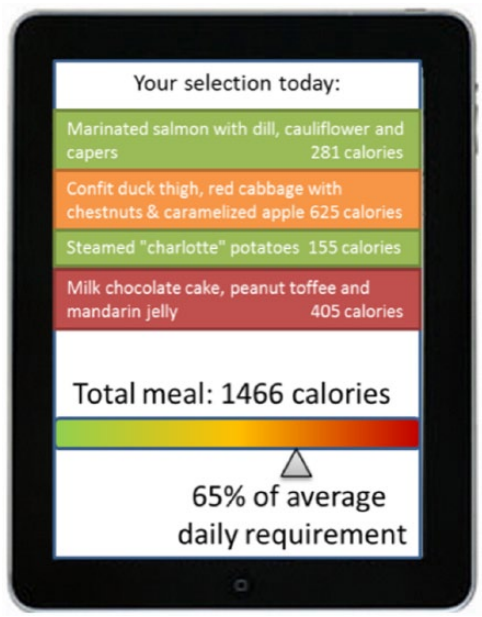

Exhibit 2:
Study Questionnaire with Questions for Each Category.

Questions Category (Number)	Sample Questions
Demographic questions (8)	Age, sex, height, weight, Nationality, year of studies, exercise, and alcohol habits
Technology questions (8)	Previously used/owned tablet and smart phone devices
	Selecting from an iPad menu seemed to me: original, easy, fun, convenient, useful . . .
	iPad increased my overall satisfaction in the ordering process.
Attractiveness/perceived influence questions (7)	I like to see (color coding/calorie information/graphic summary) on menus used in restaurants in the future.
	I find (color coding/calorie information/graphic summary) as a suitable communication tool for nutrition information.
	(Color coding/calorie information/graphic summary) is a simpler way to make healthier food choices.
	Having (color coding/calorie information/graphic summary) on menus improved my overall ordering experience.
	The (color coding/calorie information/graphic summary) influenced my food selection.
	I selected my food based on the (color coding/calorie information/graphic summary).
	Virtual menu (i.e., iPad) with nutrition information allows me to make healthier food choices than would the regular paper menu with nutrition information.
Health consciousness questions (10)	Generally healthy and balanced nutrition is important to me when I eat out.
	When shopping in general, I compare product nutrition labels.
	I am careful about what I eat to keep weight in control.
	I adjust my diet to suit my state of health.
	I am concerned about the amount of calories in the food I eat.
	To me, nutrition information is of high importance.
	Nutritional value on product labels determines what I buy.
	I try to avoid foods that are high in fat.
	I make a special effort to consume enough dietary fiber daily.
	I often search for health information on the internet.

Note. Likert-type scale of 1-5 was used where 1 = *strongly disagree* and 5 = *strongly agree* for all questions except demographic questions.

for each individual and no significant difference between six test groups, $F(125, 5) = 0.760$, $p = .554$ was detected (Exhibit 4). This nonsignificant difference provides support for the following analysis, such that any difference in attractiveness or influence measured in this study is not the result of sampling difference, in terms of health consciousness of subjects in the various groups.

PCA

Questions relating to attractiveness and perceptions of influence were similar for all groups, except for the wording of each question, which was adjusted to match the specific labeling format received by the participant (Exhibit 2). The measure of constructs between similar items within different labeling groups was analyzed using PCA with a Varimax rotation. Global diagnostic indicators showed adequate factorability of the correlation matrix with the measure of sampling adequacy, Kaiser–Meyer–Olkin, greater than the recommended .50 and the Bartlett's test of sphericity significant at $p < .001$ for all factors (Field 2009).

The PCA analysis identified the same two underlying constructs for each labeling group as originally planned in the study design, corresponding to perceived attractiveness and influence of nutrition labeling formats on food choice. In each group, the extracted constructs accounted for more than 55.4 percent of the variance. The questions were then grouped based on their loadings on each of the two extracted constructs; the average mean response was calculated for each individual's score for perceived attractiveness and influence. Exhibit 3 shows the survey questions and their corresponding PCA outcome for attractiveness and influence for each type of nutrition information presentation. Labeling groups with a combination of formats (e.g., calorie + graphic summary) received both sets of questions corresponding to each format.

Labeling Comparison

Comparisons of the five different labeling groups using a one-way ANOVA indicated a significant overall difference between labeling groups in terms of attractiveness

Exhibit 3:
PCA Results: The Factor Analysis Outcome of Survey Questions for Attractiveness and Perceived Influence of Different Labeling Groups.

Survey Questions Customized for Each Labeling Group	Color Coded		Calorie Information		Graphic Summary	
	Attractiveness	Influence	Attractiveness	Influence	Attractiveness	Influence
I like to see (color coding/calorie information/ graphic summary) on menus used in restaurants in the future.	**.883**	.161	**.737**	.223	**.926**	.014
I find (color coding/calorie information/ graphic summary) as a suitable communication tool for nutrition information.	**.840**	.265	**.795**	.209	**.832**	.018
(Color coding/calorie information/graphic summary) is a simpler way to make healthier food choices.	**.773**	.228	**.967**	.067	**.616**	.410
Having (color coding/calorie information/ graphic summary) on menus improved my overall ordering experience.	**.740**	.369	**.764**	.424	**.779**	.343
The (color coding/calorie information/graphic summary) influenced my food selection.	.189	**.810**	.233	**.881**	.127	**.885**
I selected my food based on the (color coding/calorie information/graphic summary).	.381	**.803**	.039	**.907**	.005	**.756**
Virtual menu (i.e., iPad) with nutrition information allows me to make healthier food choices than would the regular paper menu with nutrition information.	.192	**.788**	.211	**.795**	.170	**.636**

Note. Varimax rotation, Kaiser-Mayer-Olkin index (KMO) = .808 and Bartlett's test of sphericity with $\chi 2(21) = 222.079_{(21)}$, $p < .001$. PCA Loadings greater than 0.5 are indicated in bold. PCA = principal components analysis.

$F(4, 100) = 4.353$, $p = .003$. The two groups with calorie information (that is, calories alone and calories + graphic summary) showed the lowest attractiveness ranking, a value that was significantly different from the three groups with color coding (that is, traffic light alone, traffic light+ graphic summary, traffic light + calories). The response for attractiveness was highest for the group with combined traffic-light color coding plus graphic summary (Exhibit 4).

I compared respondents' self-reports of the perceived influence of menu labeling format on their food selection using one-way ANOVA and observed no significant difference between the five labeling formats, $F(4, 100) = 0.882$, $p = .477$. The traffic-light color coding plus graphic summary had the highest attractiveness and perceived influence score, but the perceived influence score was not statistically different from that of the other labeling groups (Exhibit 4).

To assess the actual influence of different nutrition labeling formats on participants' food choices, I compared total calories for selected meals using one-way ANOVA and again observed no significant difference between the total calories selected by the various labeling groups, $F(5, 120) = 0.367$, $p = .870$. The traffic-light color with graphic summary group generally chose menus with the fewest calories, but again the difference against other groups was not statistically significant (Exhibit 4). This finding matches that of the reported perceived influence, and it confirms the lack of a significant influence from different menu labeling formats on final food choice in this study.

Format attractiveness was a different story. Pearson correlation analysis found relationships between reported attractiveness and perceived influence on food selection for different labeling groups, as follows. The results revealed a significant positive correlation between perceived attractiveness and influence for color coding plus graphic summary ($r = .712$, $p < .001$) and for color coding plus calorie information ($r = .697$, $p < .001$). This correlation was not significant for the other three labeling groups (calories alone, calories + graphic summary, and traffic-light color coding alone). This finding suggests that attractiveness of menu nutrition labeling (in this case, with traffic-light color coding in addition to other information, either calories or graphic summary) is positively associated with its perceived influence on food choice.

Tablet Menu Acceptability

The respondents had a favorable opinion of the iPad-based menus, according to a descriptive analysis of the response

Exhibit 4:
Labeling Comparison: Overall Summary of Findings for All Labeling Groups in Attractiveness, Perceived Influence, and Calories Selected.

	Control No Info	Calorie Info Alone	Calorie + Graph	TL Color Alone	TL Color + Graphic	Calorie + TL Color
	n = 21	*n* = 21	*n* = 21	*n* = 21	*n* = 21	*n* = 21
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Attractiveness of nutrition label	N/A	3.14[a] (1.07)	3.27[a] (1.00)	3.76[b] (0.99)	4.15[c] (0.86)	3.93[b] (0.7670)
Perceived influence on food selection	N/A	2.90 (1.04)	2.89 (0.95)	2.95 (0.94)	3.41 (1.19)	3.11 (1.17)
Total calories selected for the meal	1,472.76 (180.35)	1,445.23 (239.73)	1,457.90 (224.38)	1,501.66 (178.10)	1,435.28 (195.38)	1,434.09 (146.53)

Note. Likert-type scale of 1-5 was used where 1 = *strongly disagree* and 5 = *strongly agree*. Different superscript letters (a, b, c; within a row) represent significant differences between means $p < .05$. TL = traffic light.

from participants in all groups. A majority of participants found the iPad menu original ($M = 4.02$, $SD = 0.912$), fun ($M = 4.02$, $SD = 0.912$), easy to use ($M = 4.41$, $SD = 0.822$), convenient ($M = 4.10$, $SD = 1.0$), useful ($M = 3.56$, $SD = 1.031$), and not time-consuming ($M = 2.19$, $SD = 1.171$) or difficult ($M = 1.57$, $SD = 0.889$). The findings highlight the attractive components of such technology in a hospitality setting, especially among young consumers.

Discussion

The findings of this study indicated that traffic-light color coding plus a graphic summary was the labeling format with the highest perceived attractiveness. In addition, there was a strong positive correlation of attractiveness with perceived influence of this labeling format on food choice. The combination of calorie information presented through traffic-light color coding, followed by more informative detailed nutrition information, summarizes their selection process. The graphic summary provided participants with a visual, accessible, and easy-to-understand representation of their meal selection, in the context of their overall daily calorie requirement.

Although traffic-light color coding alone has been previously shown to be a highly acceptable nutrition labeling format for consumer choices (Hawley et al. 2013), it appears that the color coding symbol alone does not offer enough information on the overall health impact of combined menu choices (Andrews, Burton, and Kees 2009). Given their evaluation of the attractiveness of traffic-light color coding with a detailed graphic summary at the end of meal selection, the respondents seemed to appreciate this combination. This approach allows diners to evaluate their meal's contribution in the context of their daily requirement in a simple graphic summary and decide either to maintain their original food selection or change it according to their health or indulgence objective.

The combination of traffic-light plus graphic summary labeling format confirms previous research on the effectiveness of the traffic-light system in providing useful and accessible nutrition information at the point of purchase (Morley et al. 2013). The findings of this sutdy also offer new insights into the value of using tablet technology as a tool to present relevant nutrition information in an attractive manner. The combination of simple visual cues and the facilitated percentage calculation and its graphic representation bring about a combined effect which was found to offer higher value than the simple traffic-light system.

The significant positive correlation between attractiveness and perceived influence for groups with traffic-light color coding in addition to another information (calorie or graphic summary) suggests that such color coding could influence careful food choices, even though this study found that the format had no significant impact on total calories. It is possible that this format might have a noticeable effect on calorie amounts in a different forum.

It has been previously observed that when participants are provided with factual nutrition information on different components of a meal, subjects select fewer sweets and desserts (on a hypothetical food buffet; Bucher, van der Horst, and Siegrist 2013). That principle might explain why study participants in different labeling groups might have used the available numeric information or visual cues to balance their four courses, resulting in no significant differences between the labeling groups. I suspect that the fact that there was also no significant difference with control group on calorie counts can also be partly due to this study's specific sample characteristics. The student respondents in this study are educated in food and nutrition topics as part of their curriculum, and this previous knowledge may have influenced their choices.

Implications

Research has suggested the need for more creative nutrition labeling formats to achieve the intended health benefit on consumer food choices (Dixon, Kimes, and Verma 2009). This study's use of iPad technology highlighted the benefits of this medium for drawing customers' attention to nutrition labeling in restaurants. More researchers should examine this technology for a better understanding of decision processes and consumer behavior.

From the findings of this study, it can also be concluded that although providing nutrition information in an attractive way to draw attention to the information on restaurant menus, it cannot be concluded that it has an effect on total calories selected, at least by twenty-somethings, in a full-service restaurant setting. This is an important industry implication for hospitality professionals who may consider nutrition labeling to be an interference with indulgence or upselling. Our findings seem to indicate that when nutrition labeling is attractively presented, it informs customers without causing significant changes in overall item sales. That said, there is a possibility that presentation of nutrition labeling in this way might increase customers' sense of empowerment while reducing the guilt factor (as the calorie consumption is established). Thus, customers may choose to eat in such establishments more often and become more loyal to the restaurant.

The findings of this study highlight the potential benefits of using tablet technology to provide useful information to consumers at the point of purchase. This tool can offer more attractive alternatives to menu presentation and design that may not be possible with the traditional paper menus, particularly as the tablet can be set to update calorie information as a person orders. The use of tablet technology to offer visual, animated, and detailed information on menus is an attractive approach to menu presentation that appears to be appreciated by the millennial generation. In addition to menu nutrition labeling, tablet technology allows for considerable flexibility in menu presentation.

The high acceptability of tablet technology by the youthful consumer segment seen in this study suggests important potential for innovative use of mobile tablets in restaurants, as a means for market differentiation, perhaps to attract new young clients and increase customer loyalty.

Limitations

This study measured participants' intentions rather than actual food choices, as there was never any question that the food selection would be linked to its immediate consumption (and might never be so). Therefore, evaluating participants' food choices in a real restaurant setting would be a more realistic procedure to assess the impact of nutrition labeling on food choices. However, the findings of this research study could be referenced to indicate some of the impacts to be expected if nutrition information were applied in a real setting with a similar population segment. Also, the choice of research design in this study was an *haute cuisine* menu; this may have caused participants to put aside their concerns for calorie content of their food choices in exchange for indulgence.

Another research limitation was the population demographic. While full-service restaurants constitute an ideal setting for mobile tablet menu implementation, such restaurants mostly cater to business and older clients, who have shown to value nutrition information on menus more than younger adults (Fotouhinia Yepes 2013). Therefore future studies can assess the possible impact of these labeling formats on a more representative population using a real restaurant setting. Furthermore, a similar study design can be used to provide new findings with respect to other moderating factors such as ambiance, price, and the presence of friends, which may contribute to final food decisions in real restaurant settings and allow for assessing the validity of the factors proposed in this study.

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Original contributions

The multi-disciplinary nature of this thesis offered a unique opportunity to acquire a diverse and complementary skill set in addition to novel methodological approaches to address a multifactorial condition such as obesity or NCDs. The overall thesis offers two main original contributions: 1) the role of silhouettes in monitoring obesity and its socioeconomic determinants, 2) the opportunities and limitation of using mobile technology as a tool for public health research and mHealth interventions.

The first part of the thesis validated a new research instrument, Pulvers' silhouettes show card, for obesity monitoring in low resource survey settings as well as in postal or online-based surveys. This validated instrument can be used as a measure of obesity in low resource survey settings as well as in online and mobile based surveys. The affordability and ease of use of this tool allows for more frequent monitoring of obesity not only in public health studies but also in other studies in psychology, economics and other social sciences. Facilitated monitoring of obesity using Pulvers' silhouette show cards can allow for a better understanding of the many factors which play a role in the rising prevalence of obesity and chronic diseases. This tool is valuable for monitoring obesity not only in developing countries but also in high income countries where routine anthropometric measures are not feasible in population surveys.

Additionally, silhouettes show cards are a valuable tool in assessing the social determinants of obesity, such as the ideal body size for self, ideal body size for partner and those in similar social networks. The analysis of the social influences such as ideal body size in prevalence of obesity in developing African countries can allow for targeted health intervention toward prevention of obesity in similar populations in low income countries.

Aside from the valuable role of silhouettes in obesity research, such show cards can also serve as a valuable educational tool in health promotion and obesity prevention. The use of silhouettes with the addition of traffic light color coding to highlight healthy and unhealthy body

sizes can serve as an effective educational tool in clinical setting as well as in public campaigns for obesity using TV or print media. The low literacy required to communicate healthy body size using silhouettes show cards makes it a valuable tool for obesity prevention is low socioeconomic groups. Such tool can therefore be used not only for obesity research but also to encourage healthy body size and transform social norms amongst risk populations.

In the second part of this thesis the evaluation of mobile technology provided unique insights on the potential benefits and the limitation of such tools in obesity research and NCD prevention. Through the socioeconomic assessment of the penetration of information technology in Seychelles, the research highlighted the presence of an important digital divide in Seychelles (ranked as a high income country in 2016). Despite a pervasive mobile ownership, there was an important social distinction in term of other technologies such as smart phones, computers and internet access as well as mHealth acceptance amongst older adults. These findings reveal the importance of cautionary measure when considering mHealth interventions, as it could exacerbate the existing health inequity in such countries. In coming years, it is possible that the increasing affordability and penetration of mobile phone across all socioeconomic groups can allow for bridging this digital divide and providing opportunity for equitable mHealth interventions for all.

Through development of a mobile application for food choice study, the second mobile study revealed the flexibility of tablet technology in the design of randomised control trials. The inherent flexibility in customization of mobile applications can prove revolutionary in future of health research. This study highlighted the potential for designing research studies to examine multiple experimental groups simultaneously. The success of mobile technologies in heath research however lies in a close collaboration between health professionals and software developers. Through development of carefully designed research application, mobile technology provides the opportunity to live stream data collection and provide data repositories that are more accurate, cheaper and faster. Such tools can provide the necessary insight needed for a

better understanding of health behaviour, choice analysis as well as the effectiveness of interventions for obesity and NCD prevention.

Additionally the mobile application for nutrition labelling study highlighted the potential benefit of using the interactive interface offered by tablet technology in health promotion such as nutrition labelling policies in restaurant settings to encourage healthier food choices by consumers and incentivise restaurant operators to offer healthier menu options in high income countries.

This thesis represents early instigation into novel approaches for monitoring and prevention of obesity and NCDs using silhouettes show cards and mobile technology, and further studies using these instruments are needed to expand on the preliminary evidence presented here.

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Exhibit 1: Measuring and classification details of Seychelles study variables

	Measuring details	Classification criteria
Socio-demographic Variables		
Age groups	Equally distributed age groups	25-34, 35-44, 45-54, 55-64
Marital status	(self-reported) Do you currently live alone or with a partner? (irrespective of marital status)	Married: Living with partner/spouse Single: living alone or with parents
Education	(self-reported) What is the highest level of education you have completed?	Did not completed obligatory school Completed obligatory school Attend a vocational/technical school Completed a polytechnic degree Completed university degree
Income	(self-reported) What is your personal earnings (SRP) per month, on average (incl. all allowances, benefits, etc)? (1000 SRP = $78 USD)	1: <3000; 2: 3000-5000; 3: 5000-8000; 4: 8000-15'000; 5: >15'000;
occupation	(self-reported) current occupation, categorized by interviewer	Non-qualified (labourer); Semi-qualified manual (some training); Qualified manual (trained mechanic, fisherman/farmer) Semi-qualified non-manual (clerk); Professional/ qualified non-manual (teacher);
NCD variables		
BMI	(Measured) Calculated based on measured height and weight (by a trained nurse) BMI = weight in (kg) divided by height in (m)2 and classified as per using the standard WHO categorization.	Normal weight (BMI 18.5-24.9 kg m-2), Overweight (BMI 25.0-29.9 kg m-2) Obese (BMI > 30.0 kg m-2)
Physical activity	(Self-reported) Which of the following best suits your physical activity pattern in relation to doing work in your workplace or at home?	Sedentary: sitting always or most often Moderate: often walking, standing up or carrying light weights Heavy: walking or standing up a lot, or regularly carrying heavy weights
Alcohol consumption	(self-reported) Total number of specific drink type consumed per week x its volume in ml x its alcohol in %)/7= grams of alcohol per day (10 grams of alcohol = 1 unit)	Non-drinker: 0 units /week Moderate drinker (men): 1-21 units/week Moderate drinker (women): 1-14 units/week Heavy drinker(men): > 22 unites/week Heavy drinker (women): > 15 drinker
Smoking status	(Self-reported) smoking category	Current/occasional smoker, Ex-smoker Never smoked

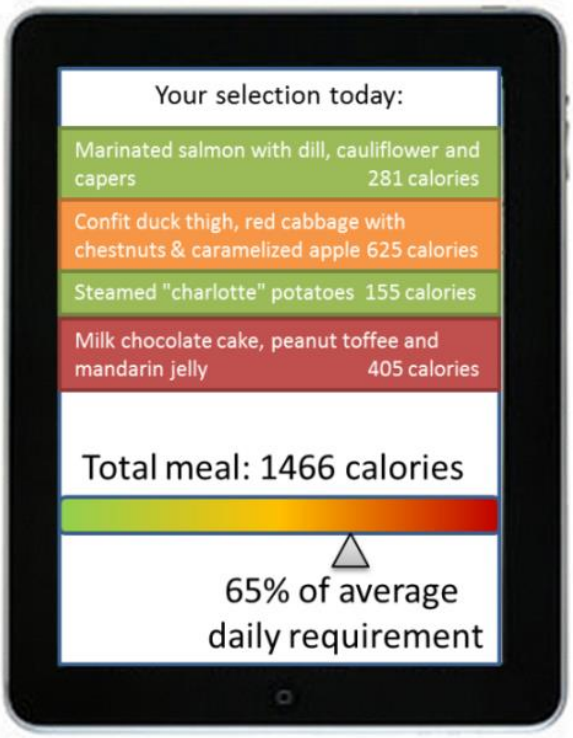
Hypertension	(Measured) Average of three blood pressure measurement by a trained nurse and grouped as per cut-off recommendation[122].	Positive: > 140 systolic or >90 Diastolic mmHg BP Negative: <140 systolic or <90 diastolic mmHg BP
Elevated blood Glucose	(measured) fasting sugar analysed on capillary blood with Contour Bayer Recommended cut off [122]	Negative: fasting plasma glucose < 6.1 mg/dl Positive: fasting plasma glucose > 6.1 mg/dl
Mobile technology assessment		
Mobile ownership	Do you have a mobile phone?	Yes or no
Internet on mobile	Can your mobile phone access Internet (e.g. iphone, android, blackberry, windows, etc)?	Yes or no
Internet use on mobile	Do you use Internet with your phone?	Yes or no
Personal Computer ownership	Do you have a tablet or computer (your own or that you can use whenever you want outside of work)?	Yes or no
Internet on PC/tablet	Do you use Internet with a computer or tablet (outside of work)?	Yes or no
email	Do you have an email address?	Yes or no
Sms for health	Would you like to receive sms (text) on your phone related to health?	Yes or no
Email for health	Would you like to receive emails related to health?	Yes or no
Mass media		
TV program on health	In the past 12 months, can you remember to have watched a program on cardiovascular disease, smoking, blood pressure, diabetes or diet on SBC TV?	Yes or no
Radio program on health	In the past 12 months, can you remember to have listened to a program on health, particularly cardiovascular disease, smoking, blood pressure, diabetes or diet on SBC radio?	Yes or no

Exhibit 2: Questionnaire used for mobile study

Questions category and (Number)	Sample questions
Demographic questions (8)	Age, sex, height, weight, Nationality, year of studies, exercise and alcohol habits
Technology questions (8)	- Previously used/owned tablet and smart phone devices - Selecting from an iPad menu seemed to me: original, easy, fun, convenient, useful… - Ipad increased my overall satisfaction in the ordering process.
Attractiveness / Perceived Influence Questions (7)	-I like to see (color coding/calorie information/graphic summary) on menus used in restaurants in the future - I find (color coding/calorie information/ graphic summary) as a suitable communication tool for nutrition information - (color coding/calorie information/ graphic summary) is a simpler way to make healthier food choices - Having (color coding/calorie information/ graphic summary) on menus improved my overall ordering experience - The (color coding/calorie information/ graphic summary) influenced my food selection - I selected my food based on the (color coding/calorie information/ graphic summary) - Virtual menu (i.e. iPad) with nutrition information allows me to make healthier food choices than would the regular paper menu with nutrition information
Health Consciousness Questions (10)	- Generally healthy and balance nutrition is important to me when I eat out. - When shopping in general, I compare product nutrition labels. - I am careful about what I eat to keep weight in control. - I adjust my diet to suit my state of health. - I am concerned about the amount of calories in the food I eat. - To me nutrition information is of high importance. - Nutritional value on product labels determines what I buy. - I try to avoid foods that are high in fat. - I make a special effort to consume enough dietary fibre daily. - I often search for health information on the Internet.

Likert scale of 1-5 was used where 1 is strongly disagree and 5 is strongly agree for all questions except demographic questions.

Exhibit 3: Sample nutrition labelling on iPad menu



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