The association between BMI self-selection, self-reported BMI and objectively measured BMI [version 1; peer review: awaiting peer review]

Emily Johnson1, Seán R. Millar2, Frances Shiely1,2,3

1School of Medicine, University College Cork, Cork, T12 AK54, Ireland
2School of Public Health, University College Cork, Cork, T12 XF62, Ireland
3Trials Research and Methodologies Unit (TRAMS), HRB Clinical Research Facility, University College Cork, Cork, T12 XF62, Ireland

Abstract

Background: It is challenging to measure BMI accurately in population studies because it is an expensive and time-consuming task. As a result, subjectively measured BMI, calculated from self-reported height and weight, which we know to be inaccurate, is often used. The purpose of this study is to determine whether using a different, subjective method of measuring BMI, BMI self-selection, would be more accurate. BMI self-selection is determined by asking participants to place themselves in one of the BMI categories, underweight, normal weight, overweight or obese.

Methods: A quantitative survey conducted in the outpatient departments of two hospitals in the South West of Ireland. Participants >18 years were included. Pregnant women were excluded. The final sample included 70 participants. Survey completion, including self-reported height and weight and BMI self-selection, preceded the objectively measured weight and height. Demographic and lifestyle factors were also recorded.

Results: 59% of the sample were overweight or obese –63% of females and 54% of males. The sensitivity for correct BMI self-selection for normal weight, overweight and obese categories was 90%, 36% and 33% respectively. The sensitivity for BMI categories calculated from self-reported height and weight was 83%, 57% and 59% respectively. In analysis, age, regular alcohol consumption, unhealthy diet and lower levels of physical activity were all associated with underestimation of BMI.

Conclusion: BMI self-selection is an accurate tool when used with normal weight individuals but shows poorer ability to demonstrate accurate measurement in overweight and obese BMI categories. It is inferior to the traditional self-reported BMI method for measuring BMI levels in the general population. Presently, we recommend continuing with self-reported BMI for BMI measurement in large
population studies. However, further testing of BMI classification in larger studies is suggested and investigation into alternative objective methods of measurement is warranted.

**Keywords**
BMI, self-reported BMI, objectively measured BMI
Introduction
Ireland has one of the highest rates of overweight and obesity worldwide, with only 40% of the population recorded as normal weight in 2015. There have been numerous studies examining the role of self-reported body mass index (BMI), defined as using self-reported height and weight to calculate BMI, compared to objectively measured BMI (BMI calculated from measured height and weight). The results of these studies report that a significant proportion of overweight and obese adults are inaccurate in reporting their height and weight when compared to objectively measured BMI. It has previously been stated that self-reported height is overestimated, regardless of gender, and self-reported weight is underestimated, by both men and women, resulting in lower BMI self-recordings. This is the case in Ireland also.

Further studies report that overweight and obese individuals have a higher tendency to misperceive their weight than normal weight individuals. In Ireland, it is reported that this bias in self-reporting height is stable over time while self-reporting weight bias has increased over time, supporting the notion of a continued increase in weight misperception and rising BMI among the Irish population. The rising level of obesity in Ireland and the corresponding lack of ability of many overweight and obese individuals to recognise their weight status has the potential to cause a catastrophic economic effect on the health service in Ireland in terms of treatment for associated conditions. Obesity is associated with hypertension, diabetes mellitus, coronary heart disease and various cancers including breast and colon cancer, osteoarthritis and fertility complications. The psychosocial consequences of obesity such as depression, anxiety, eating disorders and substance abuse, can be observed worldwide and are a burden on society as well as individuals.

Despite numerous government and public health initiatives aiming to reduce and draw attention to obesity and its causative factors in Ireland, the numbers continue to grow. There are two imperative factors in this public health emergency - firstly, the idea of weight perception and the accurate reporting of this, and secondly the normalisation of obesity in society. Obtaining an accurate figure of overweight and obese individuals is vital to predict and manage the public health services that will be required in the future. According to the World Health Organisation, Ireland is set to have the highest BMI per capita in Europe by 2030.

The aim of our study was to investigate a new means of measuring BMI for large epidemiological studies. BMI self-selection has not been evaluated previously. BMI self-selection is measured by asking individuals to self-select their BMI category, “underweight, normal weight, overweight, obese”. Our objectives were to (i) compare BMI self-selection with objectively measured BMI (calculated from measured height and weight) (ii) compare self-reported BMI (calculated from self-reported height and weight) versus objectively measured BMI (iii) determine if BMI self-selection is superior to self-reported BMI measurement at the population level (iv) establish the factors that influence an individual’s ability to correctly classify their BMI.

Methods
Study design
This was a quantitative, cross-sectional study using a self-completed questionnaire (including open ended questions) with additional measurements of weight and height. Opportunistic sampling was used at a range of outpatient clinics (ophthalmology, general surgery and gastroenterology) at Cork University and Mercy University Hospitals in the Southwest of Ireland from September 2019 to August 2020. Clinics were approached to participate while attempting to ensure a reasonable distribution of age and sex. Participants were required to be 18 years of age or older to participate in the study; pregnant individuals were excluded. Coronavirus disease 2019 (COVID-19) restrictions severely limited our opportunity to collect data in person. We availed of the limited window for data collection between wave 1 and wave 2. Clinics were not running at full capacity, so we were unable to reach our planned recruitment of 100 people before restrictions were again imposed, preventing the collection of data in person. However, this is a pilot study therefore no sample size was conducted. We adhered to the STROBE guidelines when reporting on the study.

Ethical considerations
Ethics committee approval conforming to the Declaration of Helsinki was obtained from the Clinical Research Ethics Committee of the Cork Teaching Hospitals (ECM 3bbb) 27/08/19). Permission to collect the data was sought, and granted, from the physicians in each clinic. All participants gave signed informed consent, including permission to use their data for research purposes.

Data collection
Participants were approached when they were seated waiting for their clinic appointment, or in between the appointment and waiting for a blood draw. They were given a questionnaire and asked to complete the questions to the best of their ability. Demographic variables measured included sex, age, in receipt of a medical card (proxy for socioeconomic status) and highest level of education completed. Educational levels were classified according to primary education, secondary education, some third level and completed third level, based on the education system in the Republic of Ireland. Subjects were asked to quantify their smoking status and whether they were regular users of alcohol. Participants were also asked to report their weekly exercise levels, quantified by on how many days a week they had completed at least 30 minutes of exercise, and whether they perceived their diet to be healthy, unhealthy or whether they did not know. Participants were asked to record their height and weight in the questionnaire, in whatever metric they were accustomed to, before their height and weight were measured. Subjective height and weight measurements were converted to metres and kilograms respectively. BMI self-selection was determined by asking study participants “Do you think that your BMI is “underweight, normal weight, overweight or obese?”

BMI measurement and classification
Weight and height measurements were collected by a trained researcher with reference to a standard operating procedures
manual. Weight was measured using a portable electronic Tanita WB-100MA weighing scale (Tanita Corp, IL, USA) and height was measured with a portable Seca Leicester height/length stadiometer (Seca, Birmingham, UK). The weighing scale was placed on a firm flat surface and was calibrated weekly. Participants were also asked to record their perceived height and weight in the questionnaire, in whatever metric they were accustomed to. For both objectively and subjectively measured weight and height measurements, BMI was calculated as weight in kilograms divided by the square of height in metres. Objectively measured and self-reported BMI measurements were categorised as BMI levels 18.5–24.9 kg/m² = ‘Normal-weight’, 25–29.9 kg/m² = ‘Overweight’ and >30 kg/m² = ‘Obese’.

Statistical methods
Descriptive characteristics were examined according to the full sample and by sex. Patterns of reporting bias were determined by cross-classifying objectively measured BMI categories with self-reported BMI categories (based on perceived weight and height) and BMI selection categories. BMI measurement bias was calculated as the difference between objectively measured BMI and self-reported BMI. This was recorded as a positive change, negative change or no change. Positive BMI bias implies that the participant had a higher BMI than they believed, while negative BMI bias indicates that the participant had a lower BMI than they believed, with higher positive values and lower negative values indicating greater misclassification. Independent sample t-tests or one-way ANOVA analyses were used to test mean BMI measurement bias according to sample characteristics.

Data analysis was conducted using STATATA SE Version 13 (Stata Corporation, College Station, TX, USA) for Windows. For all analyses, a P-value (two-tailed) of less than .05 was considered to indicate statistical significance.

Results
Descriptive characteristics
A total of 78 participants were recruited; six were excluded due to incomplete data; two subjects had an objectively measured BMI <18.5 kg/m² and these participants were excluded from the analyses. Characteristics of the study population for the full sample and according to sex are presented in Table 1. Of this sample, 50% had received education beyond a secondary school level, with a higher percentage of male subjects indicating lower educational levels. A greater number of male participants reported smoking every day, lower levels of physical activity and an unhealthy diet. Regarding objectively measured BMI 41.4% of participants were normal weight, 20% and 38.6% of participants were either overweight or obese respectively, and a greater number of female subjects had higher BMI levels.

BMI misclassification
Table 2 shows objectively measured BMI categories cross-classified with self-reported BMI categories (based on self-reported height and weight measurements) and BMI self-selection categories. Among normal weight subjects, 82.8% and 89.7% of participants correctly classified their BMI category according to self-reported BMI and BMI self-selection,

| Variable                                      | Full sample (n=70) | Males (n=35) | Females (n=35) |
|-----------------------------------------------|--------------------|--------------|----------------|
| **Age (median, interquartile range)**         |                    |              |                |
| Years                                         | 47.0 (28.0, 63.0)  | 47.0 (35.0, 62.0) | 47.0 (25.0, 65.0) |
| **Highest level of education completed (n, %)**|                    |              |                |
| Primary school                                | 8 (11.4)           | 6 (17.1)     | 2 (5.7)        |
| Secondary school                              | 27 (38.6)          | 15 (42.9)    | 12 (34.3)      |
| Post-leaving certificate                       | 22 (31.4)          | 10 (28.6)    | 12 (34.3)      |
| Completed third level                          | 13 (18.6)          | 4 (11.4)     | 9 (25.7)       |
| **Medical card (n, %)**                       |                    |              |                |
| Yes                                           | 27 (38.6)          | 15 (42.9)    | 12 (34.3)      |
| No                                            | 43 (61.4)          | 20 (57.1)    | 23 (64.4)      |
| **Smoking status (n, %)**                     |                    |              |                |
| Every day                                     | 11 (15.7)          | 8 (22.9)     | 3 (8.6)        |
| Occasionally                                  | 13 (18.6)          | 7 (20.0)     | 6 (17.1)       |
| Not at all                                    | 46 (65.7)          | 20 (57.1)    | 26 (74.3)      |
Variable | Full sample (n=70) | Males (n=35) | Females (n=35)
---|---|---|---
Regular alcohol consumption (n, %) | | | |
Yes | 59 (84.3) | 29 (82.9) | 30 (85.7)
No | 11 (15.7) | 6 (17.1) | 5 (14.3)
Days of exercise per week (n, %) | | | |
3 or less | 44 (62.9) | 24 (68.6) | 20 (57.1)
4 or more | 26 (37.1) | 11 (31.4) | 15 (42.9)
Healthy diet (n, %) | | | |
Yes | 43 (61.4) | 22 (62.9) | 21 (60.0)
No | 9 (12.9) | 6 (17.1) | 3 (8.6)
Do not know | 18 (25.7) | 7 (20.0) | 11 (31.4)
Objectively measured BMI category* (n, %) | | | |
Normal weight | 29 (41.4) | 16 (45.7) | 13 (37.1)
Overweight | 14 (20.0) | 5 (14.3) | 9 (25.7)
Obese | 27 (38.6) | 14 (40.0) | 13 (37.1)

*Based on objectively measured weight and height. BMI=body mass index.

Table 2. Cross-tabulation of self-reported BMI category and BMI self-selection category according to objectively measured BMI category.

| Variable | Objectively measured BMI category* | | |
|---|---|---|
| | Normal weight | Overweight | Obese | Total |
| Self-reported BMI category** | n, % | n, % | n, % | n |
| Normal weight | 24 (82.8) | 4 (28.6) | 0 (0.0) | 28 |
| Overweight | 5 (17.2) | 8 (57.1) | 11 (40.7) | 24 |
| Obese | 0 (0.0) | 2 (14.3) | 16 (59.3) | 18 |
| BMI self-selection category*** | n, % | n, % | n, % |
| Normal weight | 26 (89.7) | 9 (64.3) | 1 (3.7) | 36 |
| Overweight | 3 (10.3) | 5 (35.7) | 17 (63.0) | 25 |
| Obese | 0 (0.0) | 0 (0.0) | 9 (33.3) | 9 |

*Based on objectively measured weight and height.
**Based on participants’ self-reported weight and height.
***Based on asking study participants “Do you think that your BMI is normal weight, overweight or obese?”

Factors associated with BMI bias

Table 3 shows mean BMI measurement bias according to sample characteristics. Males were more likely to underestimate their BMI levels compared to females (mean difference = 0.75, P = .009). A one-way ANOVA of mean BMI measurement bias and age revealed that those aged 45–54 years had the
Table 3. Mean BMI measurement bias according to sample characteristics.

| Variable                                | Mean BMI measurement bias | P-value |
|-----------------------------------------|---------------------------|---------|
| Sex                                     |                           | .009    |
| Male                                    | 1.54 ± 2.1                |         |
| Female                                  | 0.19 ± 2.1                |         |
| Age range                               |                           | .018    |
| 18–24 years                             | 0.12 ± 2.3                |         |
| 25–34 years                             | -0.52 ± 2.3               |         |
| 35–44 years                             | 1.71 ± 2.0                |         |
| 45–54 years                             | 2.54 ± 2.0                |         |
| 55–64 years                             | 1.24 ± 2.0                |         |
| ≥65 years                               | 0.53 ± 2.2                |         |
| Highest level of education completed    |                           | .084    |
| Primary school                          | 0.52 ± 1.8                |         |
| Secondary school                        | 1.67 ± 2.2                |         |
| Post-leaving certificate                | 0.55 ± 2.3                |         |
| Completed third level                   | -0.6 ± 1.8                |         |
| Medical card holder                     |                           | .584    |
| Yes                                     | 1.05 ± 2.1                |         |
| No                                      | 0.75 ± 2.3                |         |
| Smoking status                          |                           | .13     |
| Every day                               | 2.05 ± 1.9                |         |
| Occasionally                            | 0.92 ± 2.7                |         |
| Not at all                              | 0.57 ± 2.1                |         |
| Regular alcohol consumption             |                           | .006    |
| Yes                                     | 1.01 ± 2.2                |         |
| No                                      | 0.09 ± 2.1                |         |
| Days of exercise per week               |                           | <.001   |
| 3 or less                               | 1.48 ± 2.1                |         |
| 4 or more                               | -0.18 ± 1.9               |         |
| Healthy diet                            |                           | .009    |
| Yes                                     | 0.22 ± 1.9                |         |
| No                                      | 2.81 ± 2.1                |         |
| Do not know                             | 1.43 ± 2.3                |         |

| Variable                                | Mean BMI measurement bias | P-value |
|-----------------------------------------|---------------------------|---------|
| Objectively measured BMI category*      |                           | <.001   |
| Normal weight                           | -0.51 ± 1.6               |         |
| Overweight                              | 0.94 ± 1.9                |         |
| Obese                                   | 2.30 ± 1.9                |         |

Mean and ± one standard deviation for the difference between objectively measured BMI and self-reported BMI is shown. P-values determined from independent sample t-tests or a one-way ANOVA. BMI = body mass index.

*Based on objectively measured weight and height.

Discussion

We examined a new way of measuring BMI, BMI self-selection. We theorised that if this was effective, BMI self-selection would change the way in which BMI measurement is reported at a population level. For a true comparison, it was necessary to collect data on objectively measured BMI (calculated from measured height and weight), self-reported BMI (calculated from self-reported height and weight) and BMI self-selection (participants self-select any of underweight, normal, overweight or obese BMI categories). Our findings show that BMI self-selection results in an underestimation of BMI in all three BMI categories, normal, overweight and obese with just 90%, 36%, and 33% agreement in the BMI categories, respectively. Comparatively, the level of agreement between objectively measured BMI and self-reported BMI, although slightly disimproved for the normal weight category at 83% is much increased for the overweight and obese categories (57% and 59% respectively). Therefore, our hypothesis that BMI self-selection would be more accurate than self-reported BMI, for measuring BMI in large population studies, is rejected.

Our results mirrored what has been previously reported, which is that individuals who are overweight or obese are poorer at recognising their overweight and...
obesity compared to individuals who are of normal weight. This was true for both BMI self-selection and self-reported BMI. Previous literature\textsuperscript{37,38,39} has cited possibilities as to why this occurs and we believe it holds true in this study also. Firstly, it may be that this group are afraid of the negative connotations that are associated with obesity and do not want to be associated with them. There is a low social desirability to be overweight and obese, which could be the reason why people do not willingly include themselves in those categories. It is also suggested that people are in denial about their weight status, associated again with the negative implications of obesity and the media portrayal of unhealthy weights. Lastly is the phenomenon of normalisation of obesity within our society. Due to the increasing rise in obesity in Ireland over time, we as a population are accustomed to seeing overweight and obese individuals in society. This has resulted in a shift in social norms – in addition to denial and negative connotations, it could be that individuals are oblivious to their own BMI status because they are increasingly seeing people with higher BMIs around them. This social norm of obesity is a topic that should be interrogated more in future studies.

Research demonstrates that adherence to healthy lifestyle behaviours is associated with a lower risk of heart disease\textsuperscript{40}, even among obese individuals. We also know that other negative lifestyle factors, e.g., not physically active at recommended levels, regular alcohol consumption, smoking and poor fruit and vegetable intake, influence our BMI levels\textsuperscript{35}. Our current study suggests that individuals who have healthier lifestyles are less likely to underestimate their BMI levels. In particular, diet plays a crucial role in weight control\textsuperscript{41}, and our results show that those who are poorer at perceiving their weight category are more likely to have an unhealthy diet or be unsure if their diet is healthy or not. Despite the aforementioned public health campaigns, this strongly suggests that these campaigns are not effectively reaching the individuals in the population who are most in need of the information and intervention. Often, these campaigns include images of morbidly obese people to whom the overweight and obese individuals in society can’t relate to and hence believe they are not at risk, a hypothesis supported in previous studies\textsuperscript{37}.

Strengths and weaknesses
Due to restrictions surrounding the COVID-19 pandemic, the collection of data was restricted for this study, resulting in a relatively small sample size. However, is a pilot study and our participants were opportunistically selected at random and therefore we believe that our results should be reasonably representative of the general population. In addition, overweight and obesity trends are consistent with the recent Healthy Ireland Study, suggesting a random sample of the population was achieved. The study excluded a proportion of the population – those that don’t accompany or attend medical appointments in hospitals. This could have resulted in skewed data because overweight and obese individuals have an increased risk of medical comorbidities that require medical care such as diabetes, rheumatoid arthritis, and cancer\textsuperscript{38,39}. However, our figures follow the Irish BMI trends, so we believe our study is a reasonable representation of the general population.

Conclusions
Though we have demonstrated that self-reported BMI is more reliable than BMI self-selection in population studies, it is still not accurate or reliable when compared to objectively measured BMI. As we can see here in Table 2, self-reported BMI is still poor for providing us with population figures in the overweight and obese categories, compared to objectively measured BMI. Researchers should still interrogate further methodologies for BMI measurement which would be more cost effective than measuring height and weight in large population studies.

Data availability
Underlying data
Zenodo: The Association between BMI self-selection, self-reported BMI and objectively measured BMI. https://doi.org/10.5281/zenodo.4644182\textsuperscript{40}.

This project contains the following underlying data:
- Archived data

Extended data
Zenodo: The Association between BMI self-selection, self-reported BMI and objectively measured BMI. https://doi.org/10.5281/zenodo.4644182\textsuperscript{40}.

This project contains the following extended data:
- Questionnaire

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).

Author contributions
EJ collected the data, drafted the manuscript and the revisions. SM guided the data analysis and oversaw the drafting of the methods section. FS conceptualised the study, contributed to the writing of the manuscript, reviewed the drafts.

Acknowledgements
We would like to acknowledge the participants in this survey who gave so generously of their time. We wish to acknowledge the Clinical Research Ethics Committee of the Cork Teaching Hospitals (CREC) for reviewing and granting ethical approval for this study.
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