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Post-exercise ingestion of lactose-free skim milk affects thirst but not subsequent performance and net fluid balance of collegiate badminton athletes

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ABSTRACT

Introduction: The hydration and nutritional needs of badminton athletes are of interest because of the unique demands of the sport on the player's physiology and skill. **Objective:** The current study investigated the acute effect of lactose-free skim milk (LFM) compared with a iso-volumic carbohydrate electrolyte sport drink (iCE) taken post exercise, on subsequent performance, net fluid balance (NFB) and other selected subjective variables (thirst, gastrointestinal comfort and palatability). **Methods:** Eleven collegiate badminton athletes (five male and six female, mean age=19.6±1.7 years, body mass=56.8±5.0 kg) volunteered to participate in this crossover study, with ≥7-day washout between trials. After a 2 h training session, the participants rested for 2 h, ingested the same volume of either LFM or iCE matched for carbohydrate content of 1.0 g carbohydrate/kg body mass. Performance tests were done post-ingestion. The body mass was taken, as well as visual analog scales administered throughout the protocol. **Results:** No significant difference between groups was found in terms of performance: aerobic capacity $t(10)$=0.147, p=0.886 and agility (sideways agility test: $t(10)$=0.191, p=0.852 and four-corner agility test: $t(10)$=0.397, p=0.700); and NFB $t(10)$=0.434, p=0.670. Thirst ratings between groups were significantly different at the end of the performance tests (LFM 6.71±2.09 and iCE 8.03±1.28, $t(10)$=-2.35, p=0.041). However, the subjective ratings for gastrointestinal comfort and palatability were similar. **Conclusion:** When matched for carbohydrate content, acute post-exercise ingestion of LFM offered a significant advantage over the sports drink in terms of thirst after subsequent performance.

Keywords: Lactose-free skim milk, collegiate badminton, net fluid balance, thirst

INTRODUCTION

The type of beverages being consumed by college level athletes is an aspect of hydration that has not been well studied. Of particular interest is the hydration effect and possible ergogenic effects of beverages. Extensive research has been done comparing water and carbohydrate-electrolyte beverages (Casa *et al.*, 2000; Shirreffs, Armstrong

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& Cheuvront, 2004; Maughan & Shireffs, 2010; Peacock, Thompson & Stokes, 2012), and most have found the latter to be more effective in maintaining better performance especially after prolonged (>60 min) activity. Cow's milk ingestion in the context of sports has recently gained popularity, mainly due to its natural composition which is rich in high quality protein, electrolytes and calcium (Roy, 2008). Research has shown that the use of low fat milk for rehydration is as good as carbohydrate-electrolyte drinks in terms of effects on hydration and performance (Lee *et al.*, 2008; James, 2012). Milk-based drinks are recommended over traditional sport drinks for post-exercise rehydration because of its energy, protein, calcium content and sodium (Desbrow *et al.*, 2014). Milk has been found to have positive effects on protein synthesis (and therefore on muscle recovery) and has shown positive results in strength gains and muscle hypertrophy (Hartman *et al.*, 2007). However, full fat milk decreases gastric emptying and therefore absorption. Hence, recent research on the use of milk by athletes has seen the use of low fat milk (Shirreffs, Watson & Maughan, 2007). Other studies have also found milk-based drinks to cause more bloating and feelings of fullness when compared with sports drinks (Desbrow *et al.*, 2014). Its fat content has also given milk a reputation of being an unsuitable sports beverage. Recommendations for its use need to be prudent as well, since certain ethnic groups, and Asians in particular, are known to have a high incidence of lactose intolerance (Heyman, 2006; Purnell, 2013).

In a study by Baguley *et al.* (2016) on the *ad libitum* intake of a milk-based supplement compared with a carbohydrate-electrolyte (CE) sports drink taken post-exercise, no difference was found in terms of net fluid balance (NFB) between the two drinks. CE sports drink however was preferred in terms of gastrointestinal tolerance and palatability. Another study found milk ingestion to be better at restoring NFB after exercise and thermal dehydration compared to CE and water (Seery & Jakeman, 2016). Similar findings were found in youth (grouped into 7-11 and 14-17 years), where skimmed milk was found to be more effective than water and CE in replacing fluid losses that occur during exercise in the heat (Volterman *et al.*, 2014). In another study, volunteers ingested either CE solution or skimmed milk after inducing a 2% body mass loss by intermittent exercise. These results suggest that milk is more effective for post-exercise rehydration because it caused a net positive fluid balance during the recovery period, even though exercise capacity 4 h afterwards was not different between both beverages (Watson *et al.*, 2008).

The intake of milk in sports has also been associated with recovery instead of having some benefit before or during activity. This may be due to preconceptions regarding its fat content and potential subsequent stomach discomfort. With the above-mentioned benefits, it would be sensible to recommend the ingestion of low fat or lactose-free milk due to the benefits from the natural components of milk without delaying absorption and stomach discomfort (Densupsoontorn *et al.*, 2004), especially in the sports setting. A study on the use of low-fat lactose-free milk showed positive effects in terms of hydration and subsequent performance of Thai endurance cyclists (Sudsa-ard *et al.*, 2014). Another study by Desbrow *et al.* (2014) compared milk-based drinks with sport drinks post-intermittent exercise, however, subsequent performance was not measured. Hence, research still has to be done on lactose-free milk and its effect on subsequent anaerobic exercise. Although several studies have been done on the effects of chocolate milk on post-exercise recovery in collegiate athletes (Spaccarotella & Andzel, 2011; Gilson *et al.*, 2010; Kitzke, Sittig & Schmidt, 2013), these were done on intermittent team sports such as soccer and basketball. No previous study was found pertaining to possible effects of drinking strategy nor ergogenic effects of milk or dairy products on performance in intermittent individual sports, specifically badminton.

Badminton offers a few key differences from other sports. The smaller size of the court area as compared to the playing areas of tennis, football, rugby, hockey and netball necessarily elicits a different movement style and specific fitness demands. Explosive movements (high intensity intermittent exercise) such as jumping, turning speed off the mark, lateral movements and agility therefore becomes extremely important (Barnard, 2008). Tests that are specific to badminton to measure the unique qualities of the sport have been developed by Chin *et al.* (1995).

Only one previous study by Abian-Vicen *et al.* (2012) analysed the influence of dehydration on strength after a competitive match of badminton players. However, no studies have been done on the possible effect of the ingestion of milk on performance variables in intermittent individual sports such as badminton. Therefore, the objective of this study was to investigate the effects of ingestion of lactose-free skim milk (LFM) against iso-volumic carbohydrate electrolyte sport drink (iCE) on badminton-specific performance and aerobic performance after intermittent sport activity. Its effect on NFB and the subjective parameters of thirst, gastrointestinal comfort and palatability were determined throughout the study.

MATERIALS AND METHODS

The collection of data was done using a randomised crossover study design, with ≥7-day washout between experimental trials (Lee *et al.*, 2008; Sudsa-ard *et al.*, 2014). Consent was given by the participants during a briefing session that was held before the screening process. The study was reviewed and approved by the Mahidol University Central Institutional Review Board with the code COA No. MU-CIRB 2017/012.0102.

Eleven collegiate badminton athletes (five male and six female; age=19.6±1.7 years; body mass=56.8±5.0 kg; data expressed as mean ± standard deviation) agreed to participate in this study. They were healthy, injury-free and had trained regularly (≥3 times per week) for the past six months. They had also previously participated in a badminton competition (at least once in the past year) at the level of university games or higher. Those with known allergies to milk or dairy products were not selected to participate in the study.

The LFM and CE that were ingested had content that was in accordance with recommendations for post-exercise carbohydrate replacement of 1.0 g carbohydrate/kg body weight (Karp *et al.*, 2006; Thomas, Morris & Stevenson, 2009; Sudsa-ard *et al.*, 2014; Spaccarotella & Andzel, 2011). The CE served as a control beverage as this was the beverage typically consumed by athletes during recovery (Spaccarotella & Andzel 2011). A water-only control was not used in this study because recommendations for post-exercise recovery requires rehydration with beverages containing fluid, electrolytes and carbohydrate. In addition the athletes were exercising in the heat where dehydration and depleted energy stores may occur (Spaccarotella & Andzel, 2011). The experimental days started and ended at approximately the same time with temperature and relative humidity in the indoor badminton facility ranging from 30.8-32.5°C (mean T°C 31.8±1.55, p=0.279) and 50-54% (mean RH% 51.8±4.97, p=0.395), respectively.

Preliminary day testing protocol

The participants were asked to arrive at the lab at 0700 hours, well rested and well hydrated. They were requested to empty their bladders, and a urine sample was collected for the measurement of urine specific gravity using a urine refractometer (Atago 300CL/URC-NM, Japan). Subsequently, body mass was determined using a Tanita RD-901 IRONMAN body composition monitor (Tanita, Japan) to establish euhydrated weight. Other baseline data, such as height (standard stadiometer), resting heart rate and blood pressure (Omron SEM-1, Kyoto Japan) were also measured. A physical activity readiness questionnaire (PAR-Q) was administered, and a brief interview was carried out for medical history and medications taken recently and at the time of data collection (Armstrong *et al.*, 2014). The participants were also asked to recall their diet and physical activity over the past 24 h and asked to replicate this the day before experimental days to ensure similar metabolic conditions (Lee *et al.*, 2008; Shirreffs *et al.*, 2007; Dion *et al.*, 2013). They were requested to avoid unusually strenuous exercise and alcohol intake 48 h and 24 h respectively, before the trials. The recommendation on fluid intake on the day before the trials was ~2.2 L/day for adult females (~58 kg) and 2.5 L/day for adult males (~70 kg) under average conditions (Howard & Bartram, 2003). A briefing on the test protocol was given to the participants on both the familiarization and experimental days, as well as the instructions they had to follow for the preliminary tests. The use of the 100 mm visual analogue scales to rate subjective perceptions of thirst, gastrointestinal comfort and palatability were explained. For thirst, the rating was from not at all thirsty (0) to very, very thirsty (10); for gastrointestinal discomfort, it was no discomfort (0) to extreme discomfort (10); and for palatability rating, it ranged from dislike very much (0) to like very much (10). The participants then did a five minute warm-up and one familiarisation trial for the performance tests (movement agility tests and shuttle run test).

Badminton-specific on-court movement agility tests

The badminton-specific on-court movement agility test that was used in this study was developed by Ooi *et al.* (2009) and was modified from the general movement and badminton-specific speed tests, as described by Hughes and Bopf (2005). These tests were used to measure the badminton-specific anaerobic performance variable in this study. Each test was done twice with a five-minute recovery that was allowed between trials and tests. The best performance time was recorded.

The players started in the ready position at central base without racket in hand. They were instructed to use badminton-specific footwork and movements during the test. The participants were required to perform the badminton-specific movement agility test that consisted of two movements, namely, the sideways-agility test and the four-corner agility test.

Five up-turned shuttlecocks were placed on each side on the line marking the outside of the single's court for the sideways-agility test. The sideways-agility test required the participants to run laterally across the width of the court for ten repetitions (five shuttles on each side), where they needed to strike the up-turned shuttlecocks with their dominant hand. The timing started when the participant began to move from the central base and stopped when the participant's feet had returned to the same base.

For the four-corner agility test, a total of 16 up-turned shuttlecocks were placed on four corners of the court, with four shuttlecocks each corner marked A, B, C and D. The participants had to strike the shuttles in order (i.e. A, B, C and then D) with their dominant hand. The timing started when the participant began to move from the central base and stopped when the participant's feet had returned to the central base.

Shuttle run

After resting 30 minutes, the participants did a 20-minute shuttle run to fatigue based on the multi-stage fitness test (Mackenzie, 2005). This test is usually used to estimate maximal oxygen uptake (VO_2max) and for testing aerobic fitness. The shuttle run involved running between two lines separated by 20 m. Computer generated beeps determined running speed and increased in frequency each minute. The onset of fatigue was determined by the failure to reach the second line for two consecutive ends. This time was recorded as time to reach fatigue and was used to compute the estimated VO_2max, as follows: $VO_2max=18.043461+(0.3689295 \times TS)+(-0.000349 \times TS \times TS)$, where TS is the total number of shuttles completed.

Experimental day protocol

One of the pre-weighed drinks, LFM or an iCE drink was randomly given to each participant at the start of the day. The drinks during the trials were maintained at 10°C (Lee *et al.*, 2008). Data was collected during the regular training schedule of the participants. They were requested to empty their bladders on arrival, and a urine sample was collected for measurement of urine specific gravity. Body mass was determined to check if they were at euhydrated weight (similar body mass and urine specific gravity during preliminary day). Clothing was limited to spandex shorts for the males and shorts and sports bra for the females during measurement of body mass. Baseline measurements for resting heart rate and blood pressure were also recorded. The FT1 Polar heart rate monitor was then worn by the participants. They were interviewed to ascertain compliance to the instructions that were given on diet, physical activity and hydration, and were also reminded of the specific instructions for the exercise protocol and the use of the analogue scales. NFB was calculated as follows:

NFB=body mass at end – body mass start protocol (pre-exercise body mass as reference point 0, adjusted for drink volume, urine output and sweat rate (Perez-Idarraga & Aragon-Vargas, 2014).

2-h training session

Each participant was requested to perform similar 2 h badminton-specific training in terms of duration and intensity of training and resting period in all experimental sessions. The heart rate was monitored to ensure similarity between trials. Plain water was given during the training at 0.4 or 0.8 L/h *ad libitum*, with the former volume provided to the slower, lighter persons and the latter given to faster, heavier individuals (Sawka & Noakes, 2007). After 1 h of training, the body mass was measured to ensure that proper hydration levels of participants (<1% body mass loss) was met. *Ad libitum* water intake was maintained until the end of the 2 h training since the participants were properly hydrated.

Beverage ingestion

After the training session, the participants rested for ten minutes and their post-exercise body mass measured. The participants then ingested the predetermined amount of LFM or iCE beverage (1 g carbohydrate per kg body mass) that was computed according to the reference values found in Table 1. Although the volume of drink was the same (1158 ml), the mean drink weights were different since LFM (which weighed 1173±104 g) was heavier than iCE (1158±103 g). Fifty percent of the amount was first ingested at 0 minutes (after measurement of post-exercise body mass), then the next 25% at 30 minutes and last 25% was ingested at 45 minutes. The bottles were opaque in an attempt to blind the participants as to their type of drink for the day. The participants were supposed to take the same volume of drink after the 2 h rest period, but due to certain limitations (time and venue), the performance tests (movement agility tests and 20 m shuttle run) were immediately done after the 2 h rest period. Urine output was collected throughout the protocol (Table 2).

The subjective measures were taken immediately before and after training, and, before and after the performance tests. Participants were instructed to freely mark their subjective ratings of thirst, gastrointestinal comfort and palatability along the line. Heart rate was measured at 10 min

Table 1. Nutrient content per 250 ml serving of LFM and CE sports drink (Gatorade brand), as indicated on the package labels

Content	*LFM*†	*Gatorade sports drink*‡
Energy (kcal)	89	67
Protein (g)	9.0	0.0
Fat, total (g)	0.3	0.0
Carbohydrate (g)	12.5	16.9
Sugars (g)	11.5	13.5
Sodium (mg)	88.0	100.4
Calcium (mg)	275.0	2.5

†Harvey Fresh Lactose Free Skim Milk brand (Australia)
‡Gatorade also contains potassium (36.6 mg) and phosphorus (24.4 mg) per 8 fluid ounce

Table 2. Body mass and NFB at different time points (N=11, $p<0.05$)

Time point	*LFM group (kg) Mean±SD*	*iCE group (kg) Mean±SD*	*LFM NFB (kg)*† Mean±SD	*iCE NFB (kg)*† Mean±SD	*Significance level*‡
Body mass					
Start protocol	56.37±4.98	56.30±5.14			
+1-hr training	56.73±4.88	56.66±5.01			
+2-hr training	56.66±4.92	56.52±5.04			
Pre-agility test	57.39±5.15	57.18±5.15			
End of protocol	56.66±5.01	56.43±5.13			
Net fluid balance					
+2-hr training			-0.69±0.82	-0.77±1.14	0.71
Pre-agility test			0.41±0.62	0.24±1.19	0.45
End of protocol			-1.54±1.23	-1.66±1.92	0.67

†NFB = body mass at end – body mass start protocol [pre exercise body mass as reference point 0, adjusted for drink volume, urine output and sweat rate (Perez-Idarraga & Aragon-Vargas, 2014)]
‡*p*-value shown for the body mass changes only after 2-hr training and NFB only

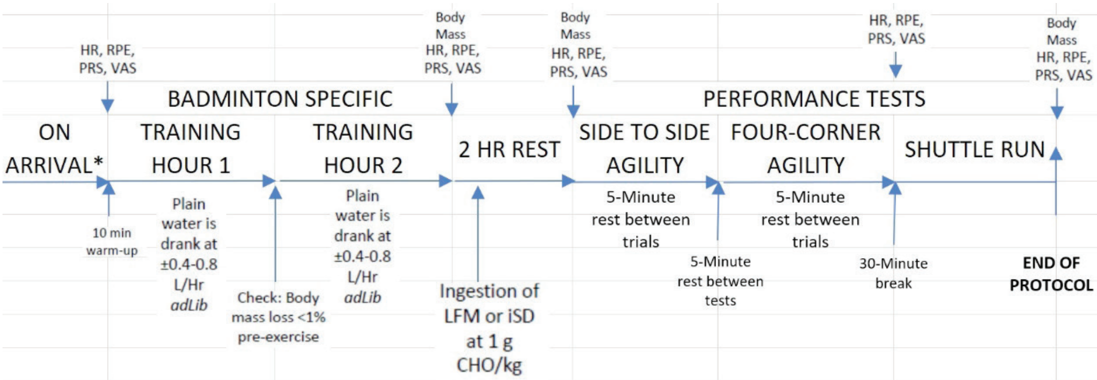


Figure 1. Experimental day protocol

intervals throughout the training and performance. The experimental day procedure is summarized in Figure 1.

Statistical analysis

Results were reported as mean±SD and significance level was set at $p<0.05$. Normality was assessed using Shapiro Wilk test and analysis of results done using paired *t*-test or Wilcoxon signed rank test, using SPSS IBM Statistical package v.20, when appropriate. Two-way repeated measures analysis of variance (ANOVA) was also used to look into the interaction of the drink and performance heart rate over time.

RESULTS

Net fluid balance

No significant difference between the LFM and iCE groups was found in terms of body mass (kg) and NFB, despite a significant difference in the mean weight of the drinks ingested [LFM:1173±104 g and iCE:1158±103 g; $t(10)=37.4$, $p=0.000$] (Table 2).

Sodium intake and drink weights for the groups were found to be significantly different ($p=0.000$), although drink volume was the same (iso-volumic conditions) (Table 3).

Subsequent performance

After the 2 h training session, the test beverages were ingested and after another hour of rest, performance tests were done as previously described. The training heart rate was similar for the LFM and iCE groups at the end of the 2 h training session $t(10)=1.98$, $p=0.076$. The performance heart rate (PHR) was measured to determine if the intensity

Table 3. Sodium content of beverages and sodium intake of participants (N=11)

	LFM Mean±SD	*iCE*† Mean±SD	*CE*‡	*p-value*
Sodium content (mg/ml)	0.352	0.297	0.402	-
Drink volume (ml)	1135.5±100.8	1135.5±100.8	-	-
Drink weight (g)	1173±104	1158±103	-	*0.000****
Sodium intake (mg)	399.7±35.5	337.3±29.9	0.0	*0.000****

†iCE – iso-volumic sport drink that was diluted to match carbohydrate content of LFM
‡CE sport drink – undiluted
***$p<0.001$

Table 4: Table of subsequent performance results (N=11)

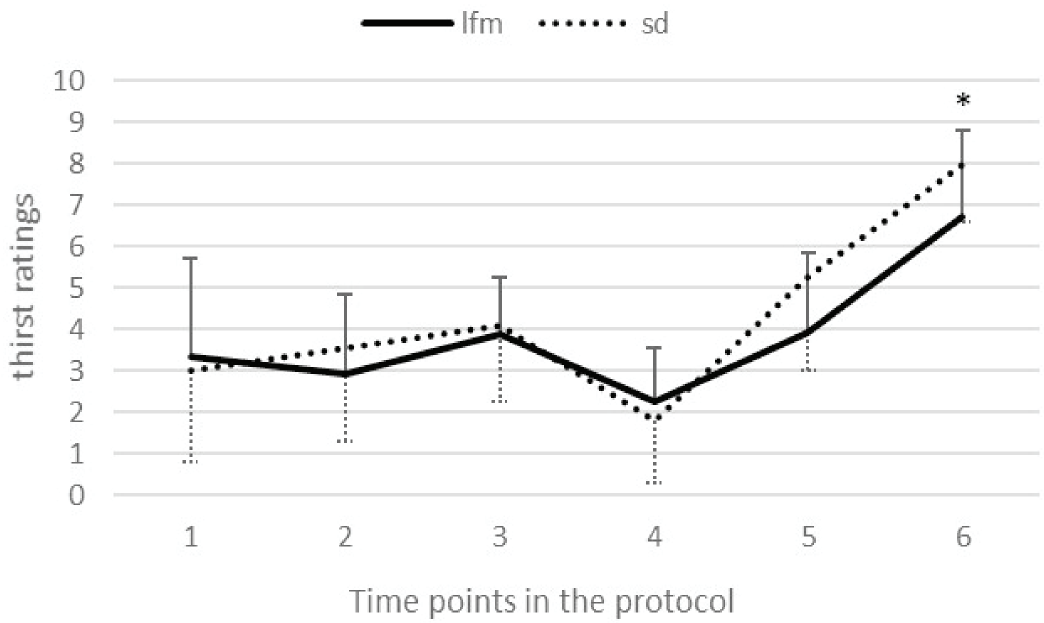
Performance variable	*LFM Mean±SD*	*iCE*† *Mean±SD*
VO_2max- *shuttle run* (ml O_2 min^{-1} kg^{-1} body mass)	38.73±8.26	38.53±4.96
Sideways agility test (sec.)	18.68±1.49	18.61±1.33
Four corner agility test (sec.)	34.77±3.48	34.36±3.49

†iCE – iso-volumic sport drink that was diluted to match carbohydrate content of LFM

of activity was similar while doing the performance tests, and to check the effect of drink on performance over time. The two way repeated measures ANOVA revealed that type of drink had no effect on PHR $F(1,10)=2.856$, $p>0.05$, and there was no interaction found between drink and PHR at the different time points $F(3.513, 35.127)=0.415$, $p>0.05$. No significant difference between groups was found in terms of aerobic capacity $t(10)=0.147$, $p=0.886$ and agility [sideways agility test: $t(10)=0.191$, $p=0.852$ and four-corner agility test: $t(10)=0.397$, $p=0.700$] (Table 4).

Subjective measures

One of the main findings in this study was a significant difference in thirst ratings between groups. Thirst ratings between groups were significantly different after the shuttle run/post-performance test [$t(10)=-2.35$, $p=0.041$] as seen in Figure 2. However, the ratings were similar for gastrointestinal discomfort and palatability.



*significant at $p<0.05$

Figure 2. Thirst ratings at different time points

DISCUSSION

NFB was not significantly different for the LFM and iCE groups as shown in Table 2. This finding was also similar to the study on a milk-based liquid meal supplement and CE sports drink done by Baguley *et al.* (2016). However, another study that compared rehydration with milk and with CE-sports drink (150% body mass loss) after exercise and thermal dehydration found milk to produce higher overall NFB (Seery & Jakeman, 2016). The nutrient composition of milk was highlighted as one of the reasons for this result. In this study, body mass for LFM group was consistently higher than iCE group although the difference was not significant. Pre-exercise body mass was used as the reference point for NFB calculations and was set as the zero (0) point. Table 2 shows us that the NFB values for both groups decreased post-training and then increased after ingestion of the beverages. This steep decrease in NFB for the post-performance test/final NFB was possibly because of the adjustment to include the sweat rate of the participants and was expected, given the hot and humid conditions during the collection of data.

Our findings on subsequent performance showed that acute post-exercise ingestion of LFM compared with carbohydrate electrolyte sport drinks had similar effects on the LFM and iCE groups. The intermittent exercise or the 2 h badminton training in this study was the protocol used for glycogen depletion. The ingestion of either LFM or iCE was done during a 2 h rest period after the 2 h training and the performance tests done after. This study protocol is similar to Sudsa-ard *et al.,* (2014) where 1 g carbohydrate/kg body mass was also ingested once before performance tests were done. Although milk has been recommended as a post-exercise recovery drink (Desbrow *et al.*, 2014; Watson, 2008; Sudsa-ard *et al.*, 2014), the results of its effectiveness on subsequent exercise are varied. Differences in the experimental procedures as well as the beverage amount ingested may have influenced the results as well. Sudsa-ard *et al.* (2014) reported that lactose-free milk ingestion increased endurance capacity in cycling compared to water and CE drink. In one study where the effects of carbohydrate versus carbohydrate-protein beverages were ingested during recovery from exhaustive aerobic exercise, the time-to-exhaustion subsequent exercise was not different between groups (Algahannam *et al.*, 2016). Even though the results did not reveal any advantage of drinking LFM over iCE, possible "day after" effects (e.g. the next 24-48 h) could have yielded positive results but it was not measured in this study. LFM is better known as a recovery drink, and its intake after training may provide an anabolic environment to help protein synthesis. Milk has the added benefit of providing additional nutrients, vitamins and minerals that are not present in commercial sports drinks. As such, it may help to correct some mineral deficiencies due to sweat loss and inadequate nutrition.

The drinks administered during experimental days were iso-volumic and matched for carbohydrate content. Since the sports drink contained more carbohydrate (Table 1), distilled water was added to it to match the carbohydrate content of the LFM. As can be seen in the table, LFM contains more nutrients and fat with a higher osmolality compared to sport drink. This explains the consistent and significant difference for drink weight for the participants despite having the same volume (of drinks).

Participants of this study rated palatability or "liking the taste" of the beverages similarly. Gastrointestinal comfort was also similar for the two beverages possibly because of the use of LFM which covers discomfort that may arise from lactose-intolerance, as well as fullness that may arise from fat in milk. LFM may also be taken in boluses, since milk is associated with poor gastrointestinal tolerance in individuals when taken in large quantities.

Some studies that measured thirst found it to be similar for milk and CE drink, but ratings for bloating and fullness were higher for milk (Desbrow *et al.* 2014). Another study found participants to prefer CE sports drink over the milk-based liquid supplement in terms of gastrointestinal tolerance and palatability (Baguley *et al.* 2016). It should be noted that LFM was not utilised, and subsequent exercise was not a variable in these studies mentioned.

Thirst ratings were found to be significantly different for the two groups. As seen in Figure 2, thirst was slightly elevated at the start of the day, which is considered normal even for euhydrated individuals (Obika *et al.*, 2009; Perez-Idarraga & Aragon-Vargas, 2014). Thirst slightly increased after training despite the *ad libitum* water intake and dropped considerably after beverage intake. The thirst sensation increased dramatically and peaked after post performance tests, with the iCE group feeling significantly more thirsty than LFM group (Figure 2). There are many factors that may influence the sensation of thirst (Greenleaf, 1992), some of which are physiological as an indicator of hypohydration (Armstrong *et al.*, 2014) and some psychological (Johnson, 2007). In a study on thirst sensations and mouth dryness after high-intensity intermittent exercise (HIIE) (compared with continuous exercise), values were higher in HIIE, albeit these were found not significant (Mears & Shirreffs, 2013). HIIE which results in increased blood lactate concentrations, serum osmolality and sweat loss was found to be the reason for greater voluntary water intake (thirst and *ad libitum* drinking) in participants. The thirst sensation increased after high-intensity intermittent exercise and remained so until participants were able to drink water despite decreasing levels of serum osmolality during recovery (Mears, Watson & Shirreffs, 2016). It was highly likely that the high-intensity intermittent exercise nature of the subsequent performance tests (badminton-specific agility tests and shuttle run) in this study could have triggered the thirst sensations to heighten for both groups.

Thirst perception increases in dehydrated persons and it was suggested that drinking decreases plasma osmolality and diminishes thirst sensation (Obika *et al.*, 2009). Milk compared to CE and water W ingestion increased plasma osmolality (Seery & Jakeman, 2016); however, they could not explain the higher NFB found for milk in that study. In our study, NFB was found to be similar for both groups, but plasma osmolality was not measured. Since the HIIE was done under hot and humid conditions and resulted in a decrease in NFB, the participants were hypohydrated, and therefore feelings of thirst increased. Thirst increased significantly and more so for the iCE group. Considering the components of LFM and CE drinks, LFM is superior in terms of energy, protein, fat and calcium compared to CE which has higher carbohydrate content (Table 1). Upon dilution of the CE to match the drinks for carbohydrate content, the resulting iso-volumic carbohydrate electrolyte sports drink iCE had a sodium content that was less than that of the LFM. This resulted in a significantly different sodium intake for the two groups [$t(10)=37.4$, $p=0.000$], where LFM group consumed more sodium compared to the iCE group (Table 3). Given the significant difference in the amount of sodium ingested for the LFM and iCE groups and a possible increase in lactate levels post-performance test, serum osmolality could have possibly increased. This is a primary stimulus for the sensation of thirst (Mears *et al.*, 2016). The post-performance thirst sensations that were found to be significantly greater for iCE group in this study may therefore be related to amount of sodium ingested which affected serum osmolality. Under extreme conditions, one may be dehydrated even before feeling thirsty (Johnson, 2007), so proper hydration throughout exercise in the heat is very important. One may use thirst sensation as a marker of hydration status since the threshold for thirst onset is hypohydration at ~2% body mass (Armstrong *et al.*, 2014).

Neither plasma osmolality nor any other markers such as serum sodium content and lactate levels were measured in this study. Due to dilution of the CE to match the drinks for carbohydrate content, it's sodium content decreased significantly and affected thirst sensations. Similar to the results of a study by Watson *et al.* (2008), the performance variables that were measured post-ingestion were not different in this study. Differences in results will ultimately depend on the type of milk ingested and other manipulations done to the drinks being tested.

CONCLUSION

The findings of this research are beneficial for lactose tolerant or lactose intolerant collegiate badminton athletes and those participating in different types of intermittent sports. Fluid balance was similar for the two groups; however, post-exercise ingestion of LFM offered a significant advantage over carbohydrate-matched iso-volumic carbohydrate electrolyte sports drink in quenching thirst at the end of the performance tests. Collegiate athletes engaged in intermittent sports may be advised to ingest LFM and milk-based drinks (if tolerated) in place of traditional CE drinks for post-exercise rehydration mainly because its nutrient content can attenuate thirst which may positively affect subsequent intermittent sport performance.

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Authors' contributions

MMFT, principal investigator, conceptualised and designed the study, led the data collection, data analysis and interpretation, prepared the draft of the manuscript; NA, conceptualised and designed the study, interpretation of data, prepared the draft of the manuscript and reviewed the manuscript; PM, conceptualised and designed the study, advised on the data analysis and interpretation and reviewed the manuscript; KS and CR reviewed the manuscript.

Conflict of interest

The authors have no conflicts of interest to report.

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Physicochemical and sensory characteristics of brown rice (*Oryza sativa*) noodles substituted with mung bean (*Vigna radiata*) powder

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ABSTRACT

Introduction: Rice noodles are widely consumed as a staple food in Asia. The main ingredient of rice noodle is polished white rice flour which lacks in nutritional components. Substitution of white rice flour with brown rice flour often results in noodles with better nutrient content but less favourable for cooking, textural and sensory characteristics. Thus, this study aimed to develop and characterise brown rice noodles substituted with mung bean powder at the level of 5% (g/100 g) and compared with other formulations. **Methods:** Four formulations of rice noodles were prepared using: a. 100% white rice flour; b. 100% brown rice flour; c. white rice flour with 5% mung bean powder; and d. brown rice flour with 5% mung bean powder. The rice noodles were produced by conventional extrusion method and evaluated for their proximate composition, cooking qualities and sensorial properties. **Results:** The results of proximate analysis indicated that protein (8.70g/100 g), dietary fibre (3.10g/100 g), ash (1.50g/100 g) and fat (2.40g/100 g) contents were significantly (p<0.05) higher in mung bean powder substituted brown rice noodles than that of white rice noodles (control). The blending of mung bean powder with brown rice flour had significantly reduced noodle cooking time and cooking loss. The sensory evaluation revealed that mung bean powder substituted brown rice noodles had similar consumer preference to control sample. **Conclusion:** The blending of mung bean powder with brown rice flour had substantially improved the nutritional value and cooking qualities of the brown rice noodles while maintaining consumer acceptability.

Keywords: Brown rice, mung bean, noodles, physicochemical, sensory

INTRODUCTION

Noodles are globally consumed especially in Asian countries such as China, Korea, Malaysia, the Philippines and Thailand (Akanbi *et al*., 2011). Rice noodles are the most consumed form of rice product next to cooked rice grain in Asia (Ahmed *et al*., 2016). Rice noodles are regarded as traditional food in China where the noodles are known as *bee hoon* (Li *et al*., 2015). According to Li *et al*. (2015), the ease of preparation has made rice noodles popular as home-cooked foods and in restaurants in southern China for many years.

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Rice (*Oryza sativa L.*) is a staple food for many countries. During the milling process, rough rice is milled to produce polished edible white rice grain by removal of the rice bran (brownish layer). This process generates rice bran and rice hull as by-products which are considered as agricultural waste (Friedman, 2013). According to Issara & Rawdkuen (2016), rice bran contains high nutritional components such as protein, lipid and phytochemicals and is beneficial for human health in terms of good antioxidant, antibiotic as well as anti-cholesterolemic values. Nutritious brown rice with intact bran and germ layers are of interest for development of various functional foods including brown rice noodles. However, findings by Baek & Lee (2014) indicated the need for future study as the percentage of cooking loss of brown rice noodles was higher than that of white rice noodles which leads to sticky texture of the former sample.

Blending of legume with white rice flour (WRF) to produce nutritious and good quality rice noodles have been reported by Yadav, Yadav & Kumar (2011), Wu *et al.* (2015) and Rathod & Annapure (2017). Legumes are valuable sources of nutrition in a healthy diet. They are known as dietary source of protein, fibre and low glycemic index carbohydrate with potential health benefits (Lee, Puddey & Hodgson, 2008; Clemente & Olias, 2017; Becerra-Tomas *et al.*, 2018). However, different legumes have unique physicochemical and functional properties (Ma *et al.*, 2017). Selection of legumes to be blended with rice flour is crucial to produce good quality noodles.

Mung bean (*Vigna radiata*) starch has been regarded as an excellent material in the processing of high quality starch noodles (Tan, Li & Tan, 2009). Mung bean is a type of green legumes which contains approximately 62.3g of carbohydrates, 27.5g of protein, 1.9g of fat, 4.6g of fibre, and substantial amount of vitamins and minerals (Mubarak, 2005). Commonly produced product from this legume is the transparent, glossy and elastic mung bean starch noodle (Tan *et al.*, 2006).

Therefore, this study aimed to study the effects of including mung bean powder (MBP) on the physicochemical and sensory characteristics of brown rice noodles.

MATERIALS AND METHODS

Raw materials and equipment

The raw materials used for this study were WRF, brown rice flour (BRF), MBP, salt and water. Stone ground WRF, whole grain BRF and mung bean (Bob's Red Mill brand) were procured from a grocery store in Selangor. The equipment used were electronic weighing scale, Panasonic blender (PSN-MX900M model), noodle extruder and steamer.

Preparation of MBP

Mung beans were soaked in water overnight. The soaked beans were drained completely the next day and left to dry at room temperature (25°C) for 24 hours. The dried beans were then ground to powder using a blender and sieved using a 40 mesh screen to obtain uniform particles. The powder was packed in airtight plastic bags and stored in a refrigerator (4˚C) until further use.

Preparation of noodles

The dough for noodles was prepared by mixing 500g-batch flour with salt and water. Four formulations of the noodles were developed, namely 100% WRF, 100% BRF, 95% WRF and 5% MBP, and 95% BRF and 5% MBP (Table 1). Preliminary studies were carried out to determine the optimum level of MBP to be added to white rice or BRF. It was found that addition of >5% MBP resulted in slightly bitter taste of the noodles.

Table 1. Formulations of noodles prepared from WRF, BRF, and mixture of rice flour and MBP

Ingredients	*Noodle Formulations*			
	100% WRF	*100% BRF*	*95% WRF + 5% MBP*	*95% BRF + 5% MBP*
WRF (g)	500	0	475	0
BRF (g)	0	500	0	475
MBP (g)	0	0	25	25
Salt (g)	8	8	8	8
Water (ml)	185	185	185	185
Total (g)	693	693	693	693

Note: WRF=white rice flour, BRF=brown rice flour, MBP=mung bean powder
Adapted and modified from Garcia *et al.* (2016)

The noodles that were prepared with 100% white rice (WRF) and brown rice (BRF) were considered as controls. The ingredients as indicated in Table 1 were mixed and dough was kneaded manually. The dough was extruded through a small hand operated noodle extruder to produce noodles with a diameter of 2mm. The rice noodles were next steamed (80-90˚C) for ten minutes prior to drying to facilitate starch gelatinisation (Ahmed *et al.*, 2016). The noodles were completely dried at room temperature (25˚C) for 12 hours and then packed in airtight plastic bags until further analysis.

Proximate analysis

AOAC methods (2005) were used to analyse the following proximate composition of noodles: moisture, fat, dietary fibre, protein and ash. Moisture content was determined by calculating the loss in weight after oven-drying of samples (AOAC 934.01). Fat was determined by Soxhlet's method (AOAC 963.15) while Kjedahl method (AOAC 960.52) was used for determining protein content. Dietary fibre was determined gravimetrically (AOAC 985.29) while ash was determined by incineration of samples using muffle furnace (AOAC 923.03). The carbohydrate content was calculated by difference, subtracting from 100 the values of moisture, ash, protein, fat and fibre. The energy value was estimated using the Atwater factors (carbohydrates = 4.0kcal g^{-1}; lipid = 9.0kcal g^{-1}; protein = 4.0kcal g^{-1}) as described by Garcia *et al.* (2016).

Cooking qualities

The cooking qualities of the rice noodles were evaluated with respect to cooking time, cooking loss and water uptake as reported by Gatade & Sahoo (2015). Noodles were cut into 3 cm length prior to cooking. Ten grams of dried rice noodles were boiled in 200 ml of distilled water to determine the cooking qualities.

Cooking time

Cooking time was determined by the removal of a piece of noodle every two minutes and pressing the noodle between two pieces of glass slides. Optimum cooking of rice noodles was achieved when the centre of the noodles becomes soft and transparent and the white core of noodles has faded away. Cooking was stopped by rinsing the noodles briefly in distilled water (Gatade & Sahoo, 2015).

Cooking loss

Cooking loss (%) was determined by measuring the amount of solid substance lost into the cooking water. Cooking water was collected in a pre-weighed glass dish and placed in a hot air oven at temperature of 105˚C and evaporated to dryness. The dry residue was weighed and cooking loss was calculated based on the following equation (Gatade & Sahoo, 2015).

Cooking loss (%) = [dried residue (g) / noodle weight before cooking (g)] x 100

Water uptake

Water uptake (%) was calculated as shown in the following equation. Cooked noodles were rinsed with water and drained for 30 seconds then weighed to determine the gain in weight of noodles (Purwandari *et al.*, 2014).

$$\text{Water uptake (\%)} = \frac{\text{[weight of cooked noodles (g) - weight of uncooked noodles (g)]}}{\text{weight of uncooked noodles (g)}} \times 100$$

Sensory evaluation

Sensory evaluation was carried out using Hedonic test with 30 semi-trained panellists consisting of students from Food Service Technology program at Management and Science University (MSU). Ethics approval was obtained from University Ethics Committee, MSU for sensory analysis. The attributes evaluated were appearance, colour, aroma, taste, texture, mouth feel and overall acceptability of the noodles. The four cooked noodle samples were prepared and filled in identical containers, coded with three-digit random numbers and each sample (10g) was presented with different codes. The randomised orders of the sample were presented one at a time to each panellist. Each panellist was requested to rate the liking on quality attributes using a nine-point hedonic scale, where one and nine represent 'dislike extremely' and 'like extremely', respectively (Ojure & Quadri, 2012; Abidin *et al.*, 2014).

Data analysis

The data obtained was subjected to one-way analysis of variance (ANOVA) and the significant difference between mean values of triplicate analyses of all parameters tested were determined by Tukey's multiple range test (p<0.05) using SPSS version 23.0 (IBM Corp., Armonk, New York).

RESULTS

Proximate composition of rice noodles

Table 2 shows the proximate compositions of four different

Table 2. Proximate composition of rice noodles prepared using WRF, BRF, and mixtures of rice flour and MBP

Proximate composition (Present as mean±SD, n=3)	*Noodle Formulations*			
	100% WRF	*100% BRF*	*95% WRF + 5% MBP*	*95% BRF + 5% MBP*
Energy (kcal/100g)	349.0±1.0^{b}	345.0±2.0^{a}	348.0±1.0^{b}	344.0±2.0^{a}
Protein (%)	6.8±0.1^{a}	7.6±0.2^{b}	8.4±0.2^{c}	8.7±0.1^{d}
Carbohydrate (%)	78.7±0.1^{d}	75.3±0.3^{b}	76.2±0.2^{c}	73.5±0.5^{a}
Fat (%)	1.0±0.1^{a}	2.1±0.1^{c}	1.4±0.2^{b}	2.4±0.3^{d}
Ash (%)	0.5±0.2^{a}	1.3±0.1^{c}	0.8±0.1^{b}	1.5±0.2^{c}
Moisture (%)	13.0±0.1^{a}	13.7±0.2^{b}	13.2±0.1^{a}	13.9±0.2^{b}
Dietary fibre (%)	1.2±0.1^{a}	2.7±0.2^{b}	1.4±0.1^{a}	3.1±0.2^{c}

Note: WRF=white rice flour, BRF=brown rice flour, MBP=mung bean powder

$^{a-d}$ Means followed by different superscripts indicate significant differences (p<0.05) within row by Tukey's HSD test

Table 3. Cooking qualities of rice noodles prepared using WRF, BRF, and mixtures of rice flour and MBP

Cooking quality (Present as mean±SD, n=3)	*Noodle Formulations*			
	100% WRF	*100% BRF*	*95% WRF +5% MBP*	*95% BRF +5% MBP*
Cooking time (min)	6.36±0.05[b]	6.28 ±0.12[b]	5.61±0.37[a]	5.47±0.09[a]
Cooking loss (%)	20.00±2.00[b]	23.33±3.06[b]	18.67±4.62[a]	16.00±4.00[a]
Water uptake (%)	12.40±0.30[a]	12.26±0.55[a]	12.60±0.36[a]	16.00±0.27[b]

Note: WRF=white rice flour, BRF=brown rice flour, MBP=mung bean powder
[a-b] Means followed by different superscripts indicate significant differences (p<0.05) within row by Tukey's HSD test

formulations of rice noodles on dry weight basis. Noodles prepared using 100% BRF had significantly higher (p<0.05) protein, fat, ash, moisture and dietary fibre content as compared to 100% WRF noodles. It was also observed that 100% BRF noodles had significantly lower (p<0.05) carbohydrate than 100% WRF noodles. Meanwhile, among the four of noodles, those developed using 95% BRF + 5% of MBP had the highest dietary fibre (3.10g/100 g) and protein content (8.70g/100 g) with the lowest amount of carbohydrate (73.50g/100 g).

Cooking qualities of rice noodles

Cooking time, cooking loss and water uptake of the four different formulations of rice noodles are shown in Table 3. Rice noodles prepared with the inclusion of MBP took shorter time to cook, approximately one minute earlier than rice noodles prepared using 100% rice flour. Significant reduction (p<0.05) of cooking loss was also noted for rice noodles with MBP (16-19%) in comparison to rice noodles without MBP (20-23%). In terms of water uptake, noodles prepared using 95% BRF + 5% MBP had the highest water uptake.

Sensory characteristics of rice noodles

The noodles developed using 95% WRF + 5% MBP had a mean score of 6-7 for most of the sensory attributes (Table 4) with means in the range of 'slightly like' to 'moderately like'. Meanwhile, lower scores were observed for taste and mouth feel attributes for 95% BRF + 5% MBP noodles with a mean score of 5.

Table 4. Acceptability score of rice noodles prepared using WRF, BRF, and mixtures of rice flour and MBP using 9-point Hedonic scale

Sensory attribute (Present as Mean±SD, n=30)	*Noodle Formulations*			
	100% WRF	*100% BRF*	*95% WRF +5% MBP*	*95% BRF +5% MBP*
Appearance	6.83±1.42[a]	6.53±1.53[a]	6.93±1.31[a]	6.63±1.30[a]
Colour	7.33±1.54[a]	6.70±1.47[a]	7.00±1.39[a]	6.67±1.58[a]
Aroma	6.50±1.23[a]	6.83±1.21[a]	6.53±1.28[a]	6.73±1.26[a]
Texture	6.97±1.45[a]	6.47±1.80[a]	6.77±1.63[a]	6.20±1.75[a]
Taste	6.73±1.70[a]	6.13±1.83[a]	6.77±1.55[a]	5.97±1.83[a]
Mouth feel	6.73±1.48[a]	6.00±2.03[a]	6.63±1.54[a]	5.80±1.97[a]
Overall acceptability	6.93±1.48[a]	6.43±2.08[a]	6.93±1.55[a]	6.20±1.85[a]

Note: WRF=white rice flour, BRF=brown rice flour, MBP=mung bean powder
[a] Means followed by same superscripts indicate insignificant differences (p>0.05) within row by Tukey's HSD test

Table 5. Appearance of rice noodles prepared using WRF, BRF, and mixture of rice flour and MBP

Noodle formulation	*Description*
100% WRF	Creamy white colour, long and firm strand, less breakable
100% BRF	Yellowish brown colour, long and less firm strand, easily breakable
95% WRF + 5% MBP	Creamy white colour, long and firm strand, less breakable
95% BRF + 5% MBP	Yellowish brown colour, long and less firm strand, easily breakable

Note: WRF=white rice flour, BRF=brown rice flour, MBP=mung bean powder

However, the mean sensory score of the sensory attributes for all the noodles did not show statistical significant difference ($p>0.05$).

Appearance of rice noodles

From visual observation, 95% BRF + 5% MBP noodles were darker in colour than the control samples (Table 5). The breakability and surface smoothness of the noodles vary according to formulations.

DISCUSSION

Findings from this study showed that noodles prepared using BRF were more nutrient dense compared to 100% WRF noodles. Higher dietary fibre, protein, fat and ash content in 100% BRF noodles in comparison to that of 100% WRF noodles is contributed by the presence of rice bran contained in the BRF. As reviewed by Issara & Rawdkuen (2016), rice bran is a potential food ingredient which can be a good source of dietary fibre, protein, fat and minerals.

Lower carbohydrate content in 100% BRF noodles as compared to 100% WRF noodles could be attributed to the presence of bran and germ in BRF. These two components of the whole grain are rich in protein, lipid and fibre that resulted in lower starch content in the BRF. In contrast, WRF made from white rice grain, in which the rice bran layer has been removed, has higher starch content resulting in higher carbohydrate content in 100% WRF noodles. Inclusion of 5% of MBP further enriched the dietary fibre, protein and fat content of BRF noodles. Abdul Aziz, Azhar Yusri & Ho (2012) have reported that MBP has 16.1% of protein, 11.5% of moisture, 3.7% of ash, 3.7% of crude fibre, 0.8% of fat and 68.0% of carbohydrate content. This data lends support to the increased level of nutrients observed in 95% BRF + 5% MBP noodles, making it a potential value-added rice noodle.

Besides nutritional values, cooking and organoleptic qualities are equally important for newly developed functional food products. According to Ahmed *et al.* (2016), good quality rice noodles should cook quickly with little cooking loss as it significantly influences the sensory properties of cooked noodles. The cooking time of rice noodles is between 5-9 minutes and the cooking loss values of rice-based noodles ranged from 6-19% (Ahmed *et al.*, 2016). In this study, noodles with the addition of MBP (95% WRF + 5% MBP, 95% BRF +5% MBP) have significantly shorter ($p<0.05$) cooking time that can be influenced by their gelatinisation properties. As reported by Wu *et al.* (2015), shorter cooking time of noodles was positively correlated with slightly lower peak gelatinisation temperature of noodles prepared using WRF blended with mung bean starch.

Cooking loss is the total solid loss in cooking water (Ahmed *et al.*, 2016). It is also highly vital to maintain structural integrity of noodles throughout the cooking process (Thomas *et al.*, 2014). High cooking loss is undesirable as the high amount of soluble starch leads to cloudy cooking water and sticky mouth feel with lower cooking tolerance (Chen *et al.*, 2002; Thomas *et al.*, 2014). Significant reduction (p<0.05) of cooking loss was noted for rice noodles with MBP (16-19%) in comparison to rice noodles without MBP (20-23%) that can be linked to the higher fibre content of rice noodles with inclusion of MBP. According to Chandra & Samsher (2013), and Kumar & Prabhasankar (2015), the fibre in noodles holds the starch network strongly and prevents starch from leaching out quickly into the cooking water. Besides that, Wu *et al.* (2015) also have suggested that rice noodles with increased amount of MBP has higher amylose content (24%) which results in stronger rice gels and lowers the cooking loss of noodles.

In terms of water uptake, noodles prepared using 95% BRF + 5% MBP had the highest water uptake. This could be attributed to its high fibre and protein contents (Table 2). Fibres and proteins are known for their ability to absorb water (Chandra & Samsher, 2013). Higher percentage of water uptake can also be related to reduced cooking time of noodles (Gatade & Sahoo, 2015). Higher water uptake promotes hydration and swelling of starch granules that reduces the gelatinisation temperature and cooking time (Ahmed *et al.*, 2016).

Sensory attributes of cooked rice noodles include colour, appearance, aroma, taste, texture and overall acceptability (Fari, Rajapaksa & Ranaweera, 2011; Ahmed *et al.*, 2016). Colour is the first parameter assessed by customers in food product. Noodles prepared using 100% WRF and 95% WRF + 5% MBP were noted to have higher acceptability scores for colour (Table 4) on a nine-point hedonic scale as compared to 100% BRF noodles and 95% BRF + 5% MBP noodles. The latter samples might be less favoured by the panellists due to the dull brown colour of the noodles that can be linked to the presence of natural pigments (carotenoids) in rice bran layer which is a component of the BRF. The acceptability score of the cooked noodles' aroma were in the range of 6.50-6.83. Aroma is regarded as a minor quality factor in sensory evaluation especially in cooked noodles due to its minimal effect on a consumer's decision towards the acceptance of a product (Ahmed *et al.*, 2016). In terms of taste and mouth feel, the degree of likeness of 95% BRF + 5% MBP noodles was the least, followed by 100% BRF noodles which might be attributed to the bitter taste of rice bran and MBP. It is known that dietary fibre is an indigestible substance with hard and coarse texture which can generate rough texture of foods (Han *et al.*, 2017). This explains the lower acceptability scores for mouth feel of 100% BRF noodles and 95% BRF + 5% MBP noodles. Although the scores vary, the differences were not statistically significant (p>0.0.5).

Visual observation of the dried noodles was recorded as it is the end product that will attract consumers to purchase. The observation indicated that 95% BRF + 5% MBP noodles were darker in colour than the control (Table 5). The 100% WRF were creamy white while the 95% WRF + 5% MBP noodles were almost as white as the former. Polished rice had its bran removed therefore giving the white rice noodles a creamy white colour. On the other hand, 100% BRF noodles also appeared as darker as the 95% BRF + 5% MBP noodles. This is related to the presence of rice bran in brown rice grains. MBP had little or no effect on the appearance of the rice noodles as only 5% of powder has been substituted with the rice flour.

Noodles developed using 100% WRF were smooth while the 100% BRF noodles had rough surface as the latter is more fibrous than the former. Noodles prepared using 100% WRF and 95% WRF + 5% MBP were long, firm and the strands were less breakable. Meanwhile, noodles developed using 100% BRF and 95% BRF + 5% MBP were long, less firm and the strands were easily breakable that could be related to lower amylose concentration in brown rice. Low amylose concentration can result in high swelling volume of starch granules which could result in softer texture of noodles (Ahmed *et al.*, 2016). However, the texture was maintained throughout cooking process as the noodles were steamed prior to drying process. Steaming is a critical step in rice noodle preparation as it will ensure proper starch gelatinisation which acts as a binder during extrusion (Malahayati *et al.*, 2015; Ahmed *et al.*, 2016).

CONCLUSION

Noodles made from BRF blended with MBP had good physicochemical and sensorial properties. These noodles had substantially higher amounts of protein and dietary fibre and were comparatively lower in carbohydrate to that of white rice noodles. The noodles also exhibited good cooking qualities, especially shorter cooking time and lower cooking loss which are considered as desirable characteristics of rice-based noodles. Consumer acceptance level is moderate for the developed brown rice noodles substituted with MBP which is comparable to the white rice noodles. Findings from this study indicated that noodles of acceptable nutritional, cooking and sensorial properties could be produced from BRF with some blend of MBP.

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Authors' contributions

SDM, carried out the experimental work, performed the data analysis and prepared the draft of the manuscript as the main author; SPG, designed the study, advised on the experimental work and data analysis, and reviewed the manuscript.

Conflict of interest

The authors have no conflict of interest.

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Effect of different pre-boiling treatment on *in vitro* protein and amino acid digestibility of mung beans [*Vigna radiata* (L.) Wilczek]

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ABSTRACT

Introduction: Mung beans [*Vigna radiata* (L.) Wilczek] are good sources of protein. Nevertheless, its protein quality is still questionable. This study aimed to determine the effect of different processes prior to boiling, on the *in vitro* protein and amino acid digestibility of mung beans by using a 6-hour enzymatic digestion. **Methods:** This study was based on the household method of the processes before boiling including unsoaking, soaking, and dehulling. Products from all treatment methods were analysed for proximate composition (moisture, crude protein, crude fat, ash, and dietary fibre) on a dry basis, naturally occurring anti-nutritional factors, amino acid composition, and digestibility of protein and amino acids. The amino acid composition and amino acid digestibility were used to calculate the dietary protein quality. **Results:** The treatments prior to the boiling of mung beans such as dehulling, soaking and without soaking, improved protein digestibility significantly by 10.8%, 10.3%, and 12.0%, respectively, when compared with that of raw mung beans (37.9%). Of the different mung bean pre-treatments, soaking seems to have the highest value of average indispensable amino acid (IAA) digestibility (55.4%), in particularly branched-chain amino acids (66.4%). However, there was no difference in the protein quality in terms of digestible indispensable amino acid score (DIAAS) across different treatment groups. **Conclusion:** The different processes performed on mung bean before boiling had only a slight impact on its amino acid digestibility and they rarely affected DIAAS values.

Keywords: Protein digestibility, protein quality, amino acid digestibility, DIAAS, pre-cooking treatment, mung bean

INTRODUCTION

Most developing countries meet their protein requirements by consuming mainly plant-based protein from sources such as legumes, seeds and pulses. These sources have recently received attention as they are environmentally friendly with a low-fat content and are cheaper than animal protein. However, the quality of plant protein is questionable (Henchion *et al.*, 2017). Protein quality is important for human life and it is likely to have

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several positive effects on growth and development as well as for promoting optimal health (FAO, 2013). High protein quality is needed to reduce childhood stunting which is associated with increased risk of metabolic diseases in later life (Arsenault & Brown, 2017). The protein quality of food depends not only on the content of its indispensable amino acids (IAAs) but also on its digestibility and, therefore, its availability (FAO, 2013).

Legumes are the important sources of protein, energy and dietary fibre. Mung bean [*Vigna radiata* (L.) Wilczek] is one of the major economic crops and is widely consumed in Asia, particularly in South, East and Southeast areas of the continent. It can be consumed as both dehulled and whole bean to make a variety of main dishes, snacks, and desserts. Generally, they are used to complement local staple foods such as rice which is deficient in lysine (Singh, D'souza & Yogitha, 2015). However, legumes have been reported to have low nutritive value because of the limited amounts of the sulphur-containing amino acids. It is also known that legumes contain several naturally occurring anti-nutritional factors, which are capable of inhibiting nutrient digestion and absorption (Gilani, Xiao & Cockell, 2012).

At the household level, soaking and dehulling are common processing techniques that are used before cooking legumes. Thermal cooking, i.e. boiling, improves the edibility and palatability of legumes. Several studies have shown that the elimination of anti-nutrients through thermal cooking treatments improve protein digestibility (Mubarak, 2005; Gilani *et al*, 2012). In addition, boiling can increase protein content in mung beans, kidney beans, chickpeas, and faba beans (El-Moniem, 1999; Wang *et al.*, 2010). With respect to amino acid composition, some studies have demonstrated increased concentrations of essential amino acids after cooking, while others have found reduced contents of methionine, tyrosine, and threonine (Candela, Astiasaran & Bello, 1997; Alajaji & El-Adawy, 2006). Although the boiling method has shown a reduction in anti-nutritive factors, a direct investigation of the impact of this process on the protein quality of mung beans has yet to be performed. In particular, studies of mung bean protein quality in terms of amino acid digestibility are scarce.

The Food and Agriculture Organization/World Health Organization (FAO/WHO) Expert Consultation on Protein Quality Evaluation has recommended the use of the Digestible Indispensable Amino Acid Score (DIAAS) method, which is based on the true ileal digestibility of each amino acid (FAO, 2013). It is necessary to consider amino acids as individual nutrients due to the differences in their bioavailability. Nevertheless, the collection of ileal fluid from the last part of the small intestine in human studies is very challenging and this invasive approach is the reason for the limited number of such studies. *In vitro* amino acid digestibility is one of the techniques that has been proposed to replace the time-consuming, costly, and invasive procedure to collect digesta from the terminal ileum, used in the *in vivo* evaluation of amino acid digestibility (Brulé & Savoie, 1988). A previous study showed that processing methods such as extrusion, baking, and cooking had impacted differently on the amino acid digestibility and DIAAS values of red and green lentils (Nosworthy *et al.*, 2018). Furthermore, soaking mucuna beans in different solutions followed by autoclaving also improved amino acid and protein digestibility (Siddhuraju & Becker, 2005). However, to our knowledge, there is no study that has investigated the effect of different preparatory processes prior to boiling, which is a household preparation method, on the amino acid digestibility of mung beans.

The aim of the present work was to determine the effect of different treatment methods prior to boiling on the *in vitro* protein and amino acid digestibility of mung beans.

MATERIALS AND METHODS

Materials

The seeds of mung beans [*Vigna radiata* (L.) Wilczek] were purchased from a local market of Thailand for the various treatments. Prior to the processing and cooking treatments, the seeds were cleaned, and the immature seeds, dust, and unwanted particles were manually removed.

Pre-thermal cooking treatment methods

No pre-cooking treatment

Untreated seeds were boiled in distilled water ratio 1:10 (weight/volume) at 100±2°C for 25 min on a hot plate, according to the procedure used in households.

Soaking

Seeds were soaked in distilled water for 7 h at room temperature, in accordance with the method of Devi *et al.* (2018). The soaked seeds were washed twice with distilled water and then boiled in the same way as the untreated mung beans.

Soaking and dehulling

Seeds were soaked in distilled water for 7 h at room temperature. After 7 h, seed coats were manually removed and the dehulled mung beans were then boiled in the same way as the untreated mung beans.

Preparation of samples

The thermally cooked samples were oven-dried at 50°C for 24 h. The unprocessed raw seeds and dried cooked samples were ground in an electric grinder at 3500 rpm for 1 min, passed through a 120-mesh screen and stored at 4°C in sealed plastic containers for further analysis.

Proximate composition

All samples were analysed for proximate composition (moisture, crude protein, crude fat, ash, and dietary fibre) in triplicate, by using standard methods of the Association of Official Analytical Chemists (AOAC) (AOAC International, 2016) and expressed on a dry basis. Moisture content was determined in accordance with AOAC method No. 990.19, by drying using a hot air oven at 100±2°C until a constant weight was achieved. Total nitrogen was analysed according to Kjeldahl's method and calculated into protein content (Nx6.25) (AOAC method No. 991.20). The factor of 6.25 was used to convert nitrogen to protein, based on a report of a Food and Agricultural Organization Technical Workshop (FAO, 2002). Total fat was analysed by acid digestion prior to continuous extraction using ether in Soxtec system (AOAC method No. 948.15, 945.16). Ash content was determined by incinerating all organic matter at 550±5°C (AOAC method No. 945.46). Carbohydrate per 100 grams was calculated using the following formula: 100-moisture-protein-fat-ash; energy was calculated using the Atwater factor (4 for protein and carbohydrate and 9 for total fat). Dietary fibre was analysed using the enzymatic gravimetric method (AOAC method No. 985.29).

Naturally occurring anti-nutritional factors

All samples were analysed in triplicate for phytic acid content, trypsin inhibitor activity, and tannin content.

Phytic acid

Phytic acid content was determined using the colorimetric method described by Gao (2007) with slight modification. Briefly, a 0.5 g sample was extracted with 10 mL of 2.4% hydrochloric acid (HCl) by using shaker at 500 rpm for 16 h and then centrifuged at 1000 g at 10°C for 20 min. One gram of sodium chloride (NaCl) was added to the crude acid extract and shaken at 500 rpm for 20 min. The extract was allowed to settle at -20°C for 20 min and then centrifuged at 1000 g at 10°C for 20 min. The clear supernatant was diluted with distilled water, following which 3 mL of diluted sample was added with 1 mL of Wade reagent (0.03% $FeCl_3.6H_2O$ + 0.3% sulfosalicylic acid). The resulting solution was mixed and centrifuged at 1000 g at 10°C for 10 min. The absorbance of colour reaction products was read at 500 nm on UV-visible spectrophotometer. Phytic acid content was calculated against the standard curve.

Trypsin inhibitor activity

Trypsin inhibitor activity was determined using a colorimetric method (AACC International, 1999). One gram of sample was extracted in 50 mL 0.01 N sodium hydroxide (NaOH) by stirring for 3 h. The extraction solution was diluted with distilled water and trypsin solution was added at 37°C, following which benzoyl-DL arginine-p-nitroanilide (BAPA) was added as a substrate. After 10 min, the reaction was stopped by adding 1 mL acetic acid. The final solution was filtered through Whatman® filter paper No.2, before measurement of absorbance at 410 nm using spectrophotometer. Trypsin inhibitor activity was reported in terms of trypsin units inhibited. One trypsin inhibitory unit (TIU) was defined as an increase of 0.01 absorbance units per 10 mL of the reaction mixture.

Tannin

Tannin was determined colorimetrically by the vanillin-HCl method (Burns, 1971). All samples were extracted with methanol at 28°C for 12 h. The decanted methanol extract was made up to 25 mL and filtered with Whatman® filter paper No.1. One mL of the extract was then treated with 5 mL of reagent mixture (1:1, 4% vanillin in methanol and 8% concentrated HCl in methanol). The absorbance of the resultant colour was read on a spectrophotometer at 500 nm after 20 min, using catechin as the reference standard. The tannin content was then calculated from a standard curve.

Amino acid analysis

The amino acid composition was determined by AOAC method No. 994.12 (AOAC International, 2016). Briefly, protein sources and dialysates were suspended in 10 mL of 6 M HCl with nor-leucine as an internal standard, in vacuum hydrolysis tubes at 121-123°C for 3 h. The suspension was diluted to 20 mL with 2 M NaOH and then filtrated through Whatman® filter paper No.42 and syringe filter with pore size 0.45 μm; 100 μL of filtrate was derivatized by N, O-bis(trimethylsilyl) trifluoroacetamide (BSTFA) with 1% trimethylchlorosilane (TMCS) prior to injection to gas chromatography-mass spectrometry (GC-MS/MS).

The instrumental conditions for the GC-MS/MS (mass spectrometer) analyses were as follows: helium carrier gas was passed at a flow rate of 3.0 mL/min through the Hewlett-Packard HP-5MS column (30 m x 0.25 mm (5%-phenyl)–dimethyl-polysiloxane column, film thickness 0.25 μm). The inlet temperature was set at 250°C. Two μL of prepared sample was injected using split mode in the ratio 3:1, with split flow rate of 3 mL/min. The GC oven temperature was increased from 100°C to 300°C at 15°C /min. The MS source and quadrupole temperatures were set at 230°C and 150°C, respectively. The MS was run in the multiple-reaction monitoring acquisition mode. Data were obtained in the full scan mode with a scan range from m/z 50 to 550. Data were collected and integrated with a personal computer using MassHunter Software.

The contents of amino acids were analysed in duplicate and presented as mg/g protein. The IAAs of each sample were compared with the recommended reference patterns for children aged 6 months to <3 years, older children aged ≥3 years, adolescents, and adults (FAO, 2013).

In vitro protein and amino acid digestibility evaluation

The *in vitro* digestion procedure was performed in triplicate and based on a two-step proteolysis with pepsin and pancreatin as described by Brulé & Savoie (1988), with minor modification. Each sample containing 250 mg protein (40 mg nitrogen) was suspended in 16 mL of 0.1 M HCl and stirred for 10 min at 37°C. The pH was adjusted to 1.9, and the hydrolysis reaction was initiated by adding 1 mL pepsin solution (1 mg/ml in 0.1 M HCl) and carried out for 30 min. The enzymatic reaction was stopped by adjusting the pH to 7.5 with 1 M NaOH and then poured into the dialysis bag [Spectra/Por® 6, molecular weight cut-off (MWCO) of 1 kDa, Spectrum Laboratories, Inc., LA, CA] of the digestion cell. The pancreatin solution (10 mg/ml in 0.01 M sodium phosphate buffer solution, pH 7.5) was added to the mixture. The digestion products were dialysed to the outer compartment of the cell and collected by circulating 0.01 M sodium phosphate buffer solution (pH 7.5) at a rate of 1.4 mL/min with a peristaltic pump for 6 h at 37°C.

The collected solution was evaporated by a rotary evaporator (Model R-124, BÜCHI, Switzerland) and adjusted to a final volume. Amino acid contents of the collected solution were determined according to the procedure mentioned earlier. Nitrogen contents of the dialysate were measured by Kjeldahl's method. The *in vitro* protein and amino acid digestibility were calculated by the following formulae:

$$\text{Protein digestibility (\%)} = \frac{\text{protein in dialysed sample x 100}}{\text{protein in sample}} \quad (1)$$

$$\text{Amino acid digestibility (\%)} = \frac{\text{amino acid in dialysed sample x 100}}{\text{amino acid in protein sample}} \quad (2)$$

Dietary protein quality determination

On the basis of protein quality, Amino Acid Score (AAS) and DIAAS were calculated as follows:

$$\text{AAS} = \frac{\text{amino acid content in 1 gram of test protein}}{\text{amino acid content in 1 gram of reference protein}} \quad (3)$$

$$\text{DIAAS} = \text{lowest digestible indispensable amino acid reference ratio} \quad (4)$$

The recommended reference pattern of IAA profile was the amino acid requirement pattern for children aged 6 months to <3 years (FAO, 2013).

Statistical analysis

All data were expressed as mean±standard deviation (SD). Statistical differences between treatments were analysed by using one-way analysis of variance (ANOVA) and Tukey's test where

Table 1. Proximate composition and naturally occurring anti-nutritional factors of mung bean (per 100 g dry weight)

Component	Raw	Cooked		
		Unsoaked	Soaked	Soaked & dehulled
Moisture (g/100 g fresh sample)	10.36[a]	61.76[b]	71.85[c]	72.40[c]
Proximate composition				
Energy (kcal)	394[a]	399[b]	397[c]	404[d]
Crude protein (g)	25.95[a]	27.37[b]	27.66[b]	29.04[c]
Crude fat (g)	1.62[a]	1.53[a]	1.15[b]	2.18[c]
Total carbohydrate (g)	68.97[a]	68.91[a]	69.05[a]	67.09[b]
Ash (g)	3.47[a]	2.18[b]	2.14[b]	1.69[c]
Dietary fibre (g)	12.15[a]	12.86[b]	15.16[c]	13.60[d]
Natural anti-nutritional factors				
Phytic acid (mg/g)	1.28[a]	0.86[b]	0.79[b]	0.71[b]
% reduction		32.38	37.85	43.95
Trypsin inhibitor (TIU/mg protein)	15.47	ND	ND	ND
% reduction		100	100	100
Tannin (mg/g)	2.40[a]	0.76[bc]	0.64[c]	0.97[b]
% reduction		68.23	73.15	59.36

Data were expressed as mean. The values within the same row with different superscript letters showed significantly differences between treatments at $p<0.05$, by one-way ANOVA with Tukey test. ND-Not detected

$p<0.05$ was considered as statistically significant. Statistical analysis was performed using SPSS software version 17.0 (IBM Corp., Armonk, NY).

RESULTS AND DISCUSSION

Proximate composition and naturally occurring anti-nutritional factors of mung bean

The proximate composition of raw and cooked mung bean seeds is presented in Table 1. The protein content of mung beans ranged from 26 to 29 g/100 g dry matter in this study. These are similar to the results reported by Dahiya *et al.* (2015). Boiling dehulled mung beans resulted in significantly higher protein and fat content, but significantly lower ash content on a dry basis ($p<0.05$) compared to raw beans. This was similar to what was reported by El-Moniem (1999). Removal of seed coat, which contained less protein and fat, would proportionally increase protein and fat in the dehulled seeds. Furthermore, the loss of soluble solids through boiling into water might improve the protein, fat, and total dietary fibre concentration in cooked seeds. Our findings are consistent with those of Wang *et al.* (2010) who demonstrated that cooking various beans and chickpeas in boiling water could significantly enhance protein, fat, and total dietary fibre content. The decrease in ash content might be attributed to the diffusion of certain minerals into the cooking water (Mubarak, 2005).

Cooking or boiling of beans is the most common method of preparation in a home setting. It decreases most of the naturally occurring anti-nutritional factors as shown in Table 1. Trypsin inhibitor activity was found to be 15.47

TIU/mg protein in raw mung beans, a value which was similar to that reported by Dahiya *et al.* (2015). Due to its thermolabile nature, trypsin inhibitor was completely destroyed by the boiling (Mubarak, 2005). It has been suggested that trypsin inhibitor was inactivated and destroyed by moist heat but not dry heat. Decreases in trypsin inhibitor levels would also be due to leaching that occurred during soaking and cooking in water (Dahiya *et al.*, 2015).

Boiling significantly decreased tannin and phytic acid content by 60-73% and 32-44 %, respectively. Similarly, Mubarak (2005) reported that boiling reduced the tannin and phytic acid content of mung bean seeds by 46% and 25%, respectively. The reduction in phytic acid content during cooking or autoclaving might be due to the loss of divalent metals (potassium, calcium, phosphorus, magnesium, iron, and manganese) which bind as the phytate-cation protein complex demonstrated by Mubarak (2005). It is possible that mung beans that are pre-soaked and dehulled prior to undergoing hydrothermal treatment may reduce that complex even further. The present study showed that the combination of soaking and dehulling of mung beans lowered the phytic acid content compared with all other treatments. However, the reduction in the tannin content was higher in cooked whole mung beans than in dehulled mung beans. These slight differences were likely caused by the distribution of condensed tannin, which is more abundant in the cotyledons of mung beans than their seed coats (Luo *et al.*, 2016). The protein digestibility can be improved when the anti-nutritional factors are decreased by cooking methods (Mubarak, 2005).

Amino acid composition

GC-MS has been widely used for amino acid analysis in food due to its high-resolution simplicity of operation and speed of analysis (Jimenez-Martin *et al.*, 2012). The amino acid composition of raw and treated mung beans is presented in Table 2, along with the amino acid profiles of casein and the patterns of IAA requirements for children and adults for comparison, as suggested by the FAO (2013). Mung beans were abundant in all IAAs except sulphur amino acids, when compared with the FAO (2013) reference. The methionine content of raw mung beans in the present study was 0.95 g/100 g protein which was within the range of 0.5-1.9 g/100 g protein that was reported by Dahiya *et al.* (2015). The content of other amino acids, except cystine, histidine and aspartic acid, were also in agreement with this report. These differing results may be attributed to the different methods used for amino acid analysis by GC-MS in this study.

Casein, which was used a reference food protein, matched with all IAAs when compared with the FAO (2013) reference pattern for adults. However, when compared with reference pattern for children, it did not match with sulphur amino acids. The foremost amino acids in casein were histidine, glutamic acid, and proline. This study showed that casein contained significantly higher amounts of isoleucine, valine, methionine, tyrosine, threonine, glutamic acid and proline than all mung bean treatments. Nevertheless, the contents of lysine, phenylalanine, alanine, aspartic acid, and glycine in casein were lower than treated mung bean.

The results of this study indicated that boiling either soaked or unsoaked beans caused a slight increase in total IAAs. They were consistent with the results of the study by El-Moniem (1999) for mung bean seeds, and that of Alajajai & El-Adawy (2006) for chickpea seeds. The small increase in total amino acid content after boiling is similar to the increase in protein content after

Table 2. Amino acid composition of raw and cooked mung bean, casein and FAO (2013) recommended allowances (g/16 g N)

Amino acids	*Raw*	*Cooked*			*Casein*	*FAO (2013)*	
		Unsoaked	*Soaked*	*Soaked & Dehulled*		*Child*	*Adult*
Indispensable amino acid (IAA)							
Branched-chain amino acid (BCAA)							
Isoleucine	3.68^{a}	3.62^{a}	3.68^{a}	3.79^{a}	4.25^{b}	3.20	3.00
Leucine	8.50^{a}	8.75^{a}	8.84^{a}	8.75^{a}	8.90^{a}	6.60	6.10
Valine	4.71^{a}	4.74^{a}	4.65^{a}	4.69^{a}	6.04^{b}	4.30	4.00
Sulphur amino acids (SAA)						2.70	2.30
Methionine	0.95^{a}	1.11^{a}	1.04^{a}	1.16^{a}	2.11^{b}		
Cystine	ND	ND	ND	ND	0.37		
Aromatic amino acids (AAA)						5.20	4.10
Phenylalanine	5.23^{a}	5.46^{ab}	5.54^{b}	5.66^{b}	4.04^{c}		
Tyrosine	2.76^{ab}	2.63^{a}	2.72^{ab}	2.81^{b}	4.93^{c}		
Lysine	7.34^{a}	8.15^{b}	8.38^{b}	7.96^{b}	5.78^{c}	5.70	4.80
Threonine	4.34^{a}	4.15^{a}	4.17^{a}	4.09^{a}	5.68^{b}	3.10	2.50
Histidine	12.38^{a}	12.07^{a}	12.16^{a}	12.74^{b}	12.12^{a}	2.00	1.60
Total IAA	49.90	50.67	51.18	51.66	54.22		
Dispensable amino acids (DAA)							
Alanine	4.30^{a}	4.20^{a}	4.22^{a}	4.40^{a}	2.88^{b}		
Arginine	6.28^{a}	6.22^{a}	6.26^{a}	6.16^{a}	4.03^{b}		
Aspartic acid	11.79^{a}	11.85^{a}	11.92^{a}	11.76^{a}	6.30^{b}		
Glutamic acid	11.53^{a}	11.34^{a}	10.84^{a}	10.73^{a}	14.94^{b}		
Glycine	4.31^{a}	4.11^{b}	4.08^{bc}	4.00^{c}	1.72^{d}		
Serine	5.59^{a}	5.51^{a}	5.45^{a}	5.30^{a}	5.31^{a}		
Proline	6.31^{a}	6.09^{a}	6.05^{a}	5.99^{a}	10.60^{b}		
Total DAA	50.10	49.33	48.82	48.34	45.78		

Data were shown as mean of two independent analyses. The values within the same row with different superscript letters showed significantly differences between treatments at $p<0.05$, by One-way ANOVA with Tukey test. ND-Not detected.

cooking. These results varied from that of Mubarak (2005) who reported that all thermal processes such as boiling, autoclaving, and microwave cooking did not increase in total IAAs.

Several studies have shown that cooking decreased lysine and total aromatic amino acids, which may be explained by destruction, Maillard reaction, and cross-linkage reactions (Alajaji & El-Adawy, 2006). However, the present study found that boiled mung bean seeds were still higher in lysine and total aromatic amino acids which were similar to the results from study of El-Moniem (1999) which revealed that cooking mung beans at 100°C for 38.6 min increased the phenylalanine and tyrosine by 5.01-10.91% when compared with raw seeds. Consistent with this result, Nosworthy *et al.* (2018) reported that boiling red and green lentils for 25-35 min had higher lysine and phenylalanine content when compared with untreated samples. In contrast, Mubarak (2005) and Alajajai & El-Adawy (2006) reported that boiling at 100°C for 90 min slightly decreased lysine and total aromatic amino acids contents. Igwe *et al.* (2012) showed that boiling at 100°C for 12 h significantly (p<0.05) reduced lysine in *Prosopis africana* and *Ricinus communis*. This may imply that the length of boiling treatment or prolonged cooking also contributed to the alteration of amino acid composition in mung bean seeds.

Protein and amino acid digestibility

Digestibility is a critical major factor affecting the quality of dietary plant proteins. When certain peptide links are not hydrolysed in the digestive process, part of the protein is either excreted in faeces, or transformed into a metabolic product by gut microorganisms present in the large intestine (van der Wielen, Moughan & Mensink, 2017). Protein quality evaluation measures the proportion of amino acids that can be absorbed from the diet and utilized in the body. An *in vitro* digestion procedure was used to determine protein digestibility in this study. This method was compared with true faecal protein digestibility in rodents and found to have a significantly high correlation (p<0.001) (Rozan *et al.*, 1997).

The preparation step of oven-drying and grinding of samples before *in vitro* digestion, which used in our current study, was similar to that used in other studies (Mubarak, 2005; Ghavidel & Prakash, 2007; Kalpanadevi & Mohan, 2013). The hot air oven-drying at 50°C during the sample preparation should not have any effects on protein digestibility since the drying at 50°C does not result in conformational changes of the protein. Based on the study of Bax *et al.* (2012), protein will change its conformation at a temperature of 70°C and that will, in turn, increase pepsin hydrolysis. The grinding of samples was performed to simulate the mechanical digestion at the mouth by teeth. Thus, oven-drying and grinding of samples may be used for the sample preparation in the *in vitro* digestibility studies.

The raw mung beans had the lowest protein digestibility among all treatments (Table 3), whereas casein presented the highest protein digestibility. The domestic cooking methods of mung beans improved protein digestibility by approximately 11%. Similar results were obtained by Barroga, Laurena & Mendoza (1985) and Mubarak (2005) who showed that protein digestibility improved by about 8-13%. The improvement in protein digestibility of mung beans by thermal cooking may be attributed to the destruction or removal of anti-nutritional factors, resulting in the easier release of nutrients than raw beans and the alteration of protein structure through denaturation. Protein denaturation by thermal treatment

Table 3. Amino acid digestibility (%) and *in vitro* protein digestibility (%) of raw and cooked mung bean after a 6-hour enzymatic digestion

Protein and amino acids	*Raw*	*Cooked*			*Casein*
		Unsoaked	*Soaked*	*Soaked& Dehulled*	
Indispensable amino acids (IAA)					
Branched-chain amino acid (BCAA)					
Isoleucine	50.2^{ab}	53.7^{b}	60.0^{c}	54.8^{bc}	47.5^{a}
Leucine	60.6^{a}	63.1^{ab}	69.3^{ab}	65.7^{ab}	74.9^{b}
Valine	64.5^{ab}	63.5^{ab}	69.8^{ab}	71.9^{b}	59.8^{a}
Sulphur amino acids (SAA)					
Methionine	52.4^{a}	42.0^{bc}	48.0^{ab}	36.8^{c}	51.6^{a}
Cystine	ND	ND	ND	ND	ND
Aromatic amino acids (AAA)					
Phenylalanine	36.8^{a}	46.8^{b}	39.5^{a}	44.7^{b}	60.6^{c}
Tyrosine	ND	ND	ND	ND	79.2
Lysine	57.9^{a}	52.9^{ab}	53.4^{ab}	49.3^{b}	70.2^{c}
Threonine	45.3^{a}	56.4^{b}	52.7^{bc}	54.1^{bc}	50.5^{ac}
Histidine	26.4^{a}	53.1^{b}	50.1^{c}	48.8^{c}	70.4^{d}
Mean of BCAA	58.4^{a}	60.1^{ab}	66.4^{b}	64.1^{ab}	60.7^{ab}
Mean of IAA	49.3^{a}	53.9^{bc}	55.4^{c}	53.3^{b}	62.7^{d}
Dispensable amino acids (DAA)					
Alanine	52.3^{a}	63.7^{cd}	54.7^{ab}	59.5^{bc}	66.6^{d}
Arginine	ND	ND	ND	ND	ND
Aspartic acid	23.4^{a}	34.1^{b}	27.0^{c}	32.0^{d}	39.5^{e}
Glutamic acid	28.1^{a}	35.9^{b}	29.3^{a}	35.0^{b}	35.9^{b}
Glycine	39.7^{a}	54.7^{b}	50.9^{b}	55.5^{b}	70.1^{c}
Serine	18.7^{a}	40.1^{b}	37.8^{b}	38.7^{b}	41.6^{b}
Proline	44.4^{a}	54.7^{b}	61.5^{bc}	57.0^{b}	64.0^{c}
Mean of DAA	34.4^{a}	47.2^{b}	43.5^{c}	46.3^{b}	52.9^{d}
Mean of total amino acids	42.9^{a}	51.1^{b}	50.3^{b}	50.3^{b}	58.8^{c}
Protein digestibility	37.9^{b}	49.9^{a}	48.2^{ab}	48.7^{a}	58.4^{a}
Relative protein digestibility (compared with casein)	65.2^{b}	85.4^{c}	82.2^{c}	83.3^{c}	100.0^{a}

Data were shown as mean of three independent analyses for protein digestibility and mean of two independent analyses for amino acids. The values within the same row with different superscript letters showed significantly differences between treatments at $p<0.05$, by one-way ANOVA with Tukey test.

could also increases polypeptide chain flexibility and accessibility to attack by proteolytic enzymes (Negi, Boora & Khetarpaul, 2001).

Soaking and/or dehulling mung beans before cooking did not further improve protein digestibility. The protein digestibility of cooked mung beans was 48-50%, which was around 82-85% relative to that of casein. These results were consistent with those of Embaby (2010) who showed that soaking and dehulling did not affect the protein digestibility of cooked sweet lupin. However, that study showed improvement in protein digestibility of soaked and dehulled bitter lupin. Similarly, Kalpanadevi & Mohan (2013) showed that there was no difference in protein digestibility after cooking unsoaked and soaked seeds. By contrast, soaking and/or dehulling of moth beans prior to pressure cooking improved protein digestibility by 3-6% when compared to the pressure cooking of unsoaked beans (Negi *et al.*, 2001). Deol & Bains (2010) found that the protein digestibility of pressure-cooked cowpea pods was slightly higher than boiled peas. These results may be attributed to the difference in cooking methods such as boiling and pressure-cooking.

For the determination of biological availability of protein in foods, the FAO/WHO Expert Consultation on Protein Quality Evaluation report recommended the use of the DIAAS by considering the true ileal digestibility of individual amino acids (FAO, 2013). To determine the amino acid digestibility, we simulated the intestinal absorption by using *in vitro* dialysis digestion. Amino acid digestibility of mung beans is shown in Table 3. The amino acid digestibility of mung beans also reflects the quality of its protein. When the amino acid digestibility of cooked mung beans was compared with that of casein, it was observed that they had lower the total amino acid digestibility than casein. Among mung bean treatments, soaked and boiled mung bean seemed to have the highest IAAs digestibility, which was 55.4%.

All mung bean treatment methods had similar branched-chain amino acid digestibility when compared to that of casein. Soaked mung beans and those that were soaked and dehulled exhibited isoleucine digestibility of 60.0%, and 54.8% and valine digestibility of 69.8%, and 71.9%, respectively, which were higher than those available from casein. These results were consistent with those of Brulé & Savoie (1988) who reported that isoleucine and valine digestibility of field peas, rapeseeds, and soybeans were higher than that of casein. However, phenylalanine and lysine digestibility of cooked mung beans was lower than those of casein even though the former contained more phenylalanine and lysine. Lysine and methionine digestibility tended to decrease after boiling whereas phenylalanine, threonine and histidine digestibility slightly increased after hydrothermal treatments.

In heat-processed food, methionine, cysteine, and lysine can be oxidized or react with compounds to form unavailable derivatives such as methionine sulphoxide, methionine sulphone, as well as cysteic acid. Rutherfurd & Moughan (2012) also reported that the available amino acid content determined by the difference between ingested amino acid and remaining undigested amino acid at terminal ileum may not be accurate because the unabsorbed amino acids contained in foods can revert to available forms during hydrolysis step of analysis leading to overestimation of available amino acids. Furthermore, for determining true ileal amino acid digestibility, the endogenous losses of amino acids need to be considered. These losses depend on the contents of dietary fibre, body weight of animal models and the alteration of bacterial nitrogen. Endogenous ileal amino acid losses are significant especially in malnourished people, elderly and patients with inflammatory bowel diseases (Gaudichon *et al.*, 2002).

Consequently, these factors may cause changes in the amino acid composition of ileal fluid and lead to a biased estimation of the endogenous amino acid loss. Therefore, an *in vitro* digestion procedure might overcome the downside of true ileal digestibility method due to the difference in the sample collection from dialysate (available) and digesta (unavailable), and reduce the bias in endogenous losses of amino acids.

Protein quality determination

The AAS and the DIAAS for the determination of protein quality are presented in Figure 1. The AAS and DIAAS values of soaked and cooked mung beans were 0.39 and 0.19, respectively for the sulphur amino acids. These scores indicated that AAS was higher than DIAAS, which was due to the digestibility correction. It may imply that the digestibility measurement of each amino acid is very important especially for plant protein. Similar results were obtained by Nosworthy *et al.* (2018) for red and green lentils. Our results indicated that the value of AAS did not reflect the quality of plant-based protein. According to the recommendation of the FAO (2013), DIAAS is a recent method that is used to measure the protein quality; however, this approach is based on ileal digestibility, which is very invasive rather than faecal digestibility.

The DIAAS values of raw, unsoaked, soaked, soaked and dehulled boiled mung beans were 0.18, 0.17, 0.19, and 0.16, respectively for the sulphur amino acids, which had no difference among all mung bean treatments. These results were in agreement with those of the study by Hodgkinson *et al.* (2018)

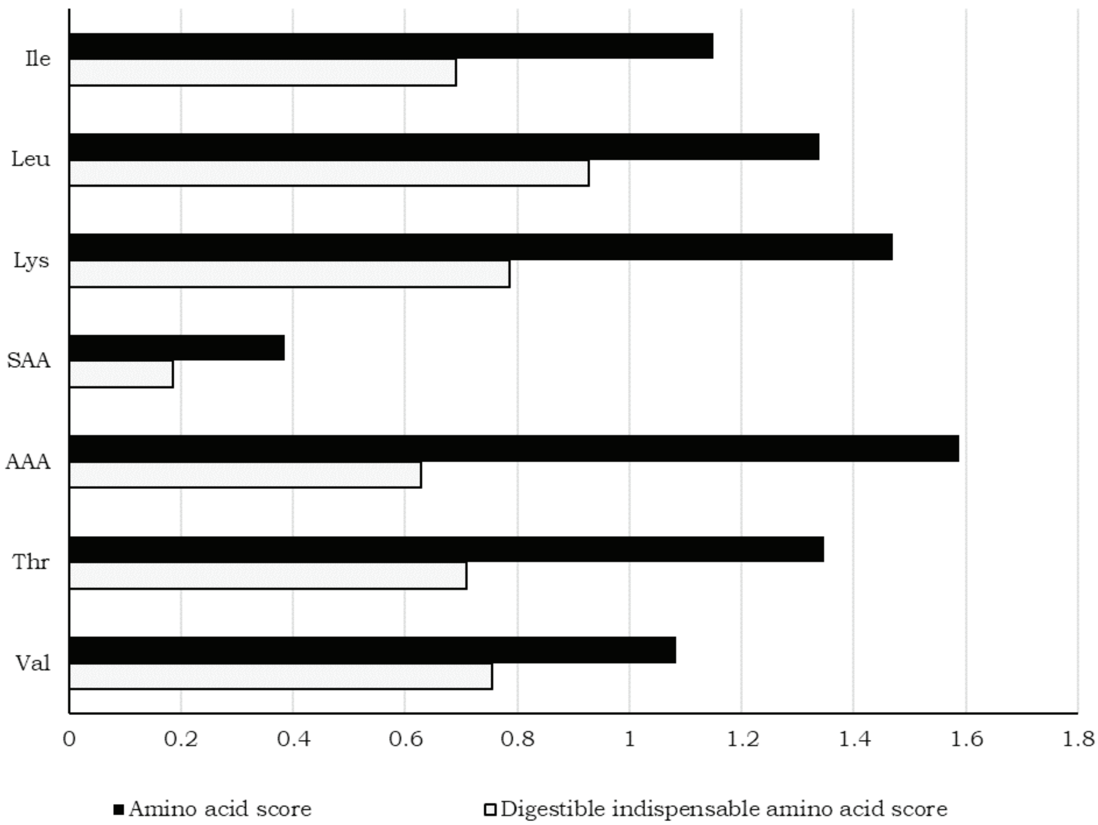

Figure 1. Protein quality determination of soaked cooked mung bean

Data were calculated using the reference pattern for children aged 6 months to <3 years.
Ile: Isoleucine, Leu: Leucine, Lys: Lysine, SAA: Sulphur Amino Acid, AAA: Aromatic Amino Acid, Thr: Threonine, and Val: Valine.

who determined the effect of cooking processes on DIAAS of beef. They found that the DIAAS did not differ between raw and boiling meat but was lower in grilled and roasted beef. Consistent with these results, the previous study of Nosworthy *et al.* (2018) revealed that baking exhibited lower DIAAS than boiling and extrusion of legumes. It may be concluded that DIAAS would differ when the severe thermal cooking processes such as baking, grilling, and roasting are performed, but would not differ after boiling.

CONCLUSION

The processing techniques of soaking and dehulling prior to boiling increased the *in vitro* amino acid digestibility of mung beans, especially those of branched-chain amino acids. However, they did not further improve the overall quality of proteins determined by DIAAS. It could be due to the fact that boiling was not a severe thermal cooking method. The present findings concluded that boiling, where the cooking temperature does not exceed 100°C, is a good hydrothermal cooking procedure and it does not affect the protein quality. Mung beans were shown to have a small amount of sulphur-containing amino acids. As such, complementary amino acids from other food sources are needed for ensuring adequacy of these amino acids. This study did not determine the tryptophan concentrations of all samples due to the limitation of the amino acid analysis method. The *in vitro* digestion method should be further validated in terms of amino acid digestibility and compared with *in vivo* method to determine true ileal amino acid digestibility. However, the *in vivo* technique in animals or humans is invasive, costly, requires specific instruments and is time-consuming.

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Authors' contributions

AP, performed the study, analysed the data and drafted the manuscript; WK, designed the study, conducted the data interpretation, and reviewed the manuscript; JK, designed the methodology and analysed the data; AK, advised on the methodology and the data analysis; PC, advised on the methodology.

Conflict of interest

The authors declared no conflict of interest.

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Insights into knowledge, attitude and practices on early complementary feeding of infants among Saudi mothers

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ABSTRACT

Background: The World Health Organization recommends that mothers avoid early complementary feeding of infants before the age of 6 months, to promote maximum growth and health. However, this practice is still high among Saudi mothers. This study aimed to assess knowledge, attitude and practices (KAP) towards early complementary feeding among Saudi mothers in Riyadh. **Methods**: A cross-sectional study was conducted in Riyadh city among 771 mothers of children, aged 6-24 months. Data was collected through an online questionnaire that assessed KAP aspect regarding early complementary feeding among mothers. **Results**: More than one-third of mothers (37.4%) had introduced early complementary feeding, out of which 83.3% later stated that the main reason for this was because they thought that the baby was old enough to receive complementary foods. The two most common types of complementary foods given to the baby before 6 months were liquids (83.0%) and mashed foods (72.9%). The mothers who introduced complementary feeding before 6 months of age compared to those who initiated complementary feeding after 6 months were observed to have a higher percentage of medium knowledge and neutral attitude (76.0% versus 54.4% and 55.2% versus 62.5%, ($p<0.05$), respectively). Mothers' knowledge and attitude significantly influenced their practices in relation to early complementary feeding ($p<0.05$). **Conclusion**: The findings demonstrated that the appropriate knowledge and attitude are important to promote the introduction of complementary feeding at 6 months in the population that was studied. Thus, education on complementary feeding should be promoted.

Keywords: Knowledge-attitude-practices, complementary feeding before 6 months, Saudi mothers

INTRODUCTION

Nutrient adequacy is crucial in the periods of infancy and early childhood, as it is necessary for ideal growth, health and development. The World Health Organization (WHO, 2003), has stated that complementary feeding should start when breast milk alone is no longer sufficient to meet the nutritional requirements of infants, and therefore other food and liquids are needed, along with breast milk. It has recommended that mothers breastfeed their infants from birth until they reach the age of 2 years and that complementary feeding should not be introduced before 6 months of

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age. Thus, early complementary feeding is the introduction of foods other than breastmilk to infants before the age of 6 months (WHO, 2003).

Infants who had been exposed to early complementary foods (before 6 months) were at higher risk of consuming foods and fluids that had microbial contamination (Tang, Lee & Binns, 2015). According to a study conducted in India, infants under 6 months of age were showed to have gastrointestinal system, kidneys and neurodevelopment that were not fully developed (Ip *et al.*, 2009). Another study concluded that infants who were fed exclusively with formula had a higher risk of developing acute otitis media compared to those infants who were exclusively breastfed (Rao *et al.*, 2011). In several countries of Middle East and North Africa region (the so-called MENA region), such as United Arab Emirates (UAE), Lebanon, Kuwait, Libya, Egypt, Bahrain and Yemen some mothers introduce non-milk fluids such as sweetened water and herbal teas to their infants who are under 6 months. Such a practice also appeared to be related to diarrhoea in infancy (Radwan, 2013; Batal, Boulghourjian & Akik, 2011; Al-Awadi & Amine, 1997; Shembesh, Balo & Singh, 1997; El Mougi *et al.*, 1981; Al-Sairafi & Al-Dallal, 2002; Central Statistical Organization, 1994). In addition, a systematic review revealed that infants who had been exposed early to solid foods were at higher risk of being overweight in childhood (Pearce, Taylor & Langley-Evans, 2013). The knowledge of appropriate nutrition of mothers has been demonstrated to have an important role on how the child will be fed. However, a study done in Kosova showed that although 88.4% of mothers had sufficient knowledge of complementary feeding, only 38.4% of them were willing to apply that knowledge (Berisha *et al.*, 2017).

In terms of practice, research studies on complementary feeding conducted in the Kingdom of Saudi Arabia (KSA) and Kuwait showed that the recent feeding practices were falling behind in their compliance with the WHO recommendations (El Mouzan *et al.*, 2009; Scott *et al.*, 2015). An earlier study done in the city of Riyadh in the KSA found that 51.4% of infants were formula fed by 1 month of age and 90% by 6 months of age, while 80.8% were introduced to solid food at the age of 4-6 months (El Mouzan *et al.*, 2009).

The theory of planned behaviour describes the linkage between knowledge, attitude and practices (KAP) among people in health studies (Manderson & Aaby, 1992; Launiala, 2009). There are a few studies on early complementary feeding in Saudi Arabia but none on early complementary feeding that have explored KAP of mothers in Saudi Arabia. This study was conducted to investigate the KAP of early complementary feeding among mothers in Riyadh.

MATERIALS AND METHODS

Study design and subjects

This cross-sectional study was undertaken in Riyadh city, from January to March 2019. A total of 771 Saudi mothers participated in the study. They fulfilled the following inclusion criteria: resident in Riyadh, were at procreative age (18-45 years old), have had a child age 6-24 months, have had infants without chronic diseases or metabolic disorders or health complications and were mothers of full-term infants. Ethical approval was obtained from the Institutional Review Board of Princess Nourah Bint Abdulrahman University (H-01-R-059/ 18-0364). All participants were fully aware of the requirements for participation and were informed that their participation was voluntary.

Data was collected using a convenient sampling technique through an online questionnaire.

Research tools

The KAP questionnaire was adapted from a previously validated questionnaire (Kittisakmontri *et al.*, 2018) and translated to Arabic and then translated back to English. It was modified before the back translation to meet the objectives of this study. To guarantee clear and ease of understanding by the participants, the questionnaire was tested among 23 individuals. Section 1 of the questionnaire contained questions about general information of mothers and demographic characteristics of the infants, such as mother's age, number of children level of education, occupation, income, child's gender, and age. Section 2 of the questionnaire focused on measuring KAP, as follows:

- Knowledge: questions on the knowledge of the mothers on the appropriate age for the introduction of complementary foods, the types of foods introduced prior to 6 months and their source(s) of information.
- Attitude: questions that assessed the attitude of mothers towards the introduction of liquids and semi-solid foods, and the sufficiency of breast milk to their infants before the age of 6 months.
- Practices: this assessment contained questions on the age of the infant at which mothers started the introduction of complementary foods, reasons that drove them to initiate early complementary feeding, the texture and characteristics of the early foods that were introduced.

To assess the interrelationship between the three aspects of KAP, a score was assigned for each of them.

Both knowledge and attitude were divided into three equal levels by dividing the total score of each aspect on 33.3% for the lowest level, 33.4-66.6% for medium level and 66.7-100.0% for the highest level. Categorisation was based on the total score obtained for each aspect. For knowledge, each correct and wrong answer was scored as 1 point and 0 point, respectively. Answers for attitude ranged from strongly disagree to strongly agree. These were scored as 4 points for strongly disagree, 3 point for disagree, 2 points for neutral, 1 point for agree and zero point for strongly agree. For practices, categorisation was based on the answer to the question, "when did you introduce complementary food to your child?". Score was 0 and 1 for introducing the complementary feeding before and after 6 months of age of the infant, respectively.

Statistical analysis

The data was collected from the questionnaire, entered and analysed using the SPSS programme version 21. The total population was divided into two groups, based on the time complementary feeding was initiated: Group 1 (<6 months) defined as mothers who started introducing complementary feeding before 6 months of infant's age (n=288); and Group 2 (>6 months), defined as mothers who started introducing complementary feeding after 6 months of infant's age (n=483). Descriptive statistics were presented as percentage (%). To assess the differences between the two groups and the interrelationship between KAP variables, the Pearson correlation and chi-square tests were used. The results were considered statistically significant when p-value <0.05.

RESULTS

Social demographic

Of a total of 771 mothers who participated in the study, 37.4% (288)

had introduced early complementary feeding while 62.6% (483) had introduced complementary feeding after 6 months of the infant's age. In terms of the socio-demographic data, results showed that majority of mothers who introduced early complementary feeding were those with diploma or bachelors degree educational level (71.9%) and mothers with first-born infant (28.5%). However, there was no significance in the socio-demographic data between mothers who introduced complementary feeding before and after 6 months of age (Table 1).

Knowledge

Our results in Table 2 showed that the majority of the participants (65.5%) had chosen 6 months or later as an appropriate age for the introduction of complementary feeding among all mothers, indicating that they possessed knowledge that matched the WHO recommendation. In addition, 73.9% agreed that the most important factor to promote infant growth was exclusive breastfeeding for at least 6 months. Among the total of 483 (62.6% of all mothers) who introduced complementary feeding after 6 months or later, 90.9% of them chose 6 months as the appropriate age to start. Of a total of 288 mothers (37.4% of all mothers) who had introduced early complementary feeding, 40.9% of them had chosen 4 months as an appropriate age to start introducing complementary food.

There was a significant difference in the knowledge of mothers about the time for the introduction of semi-solid foods. The proportion of mothers who chose semi-solid as an appropriate food to be added before 6 months of age was 63.2%, whereas 34.0% chose semi-solid food as an inappropriate food to be added before 6 months of age (p=0.000).

There was no significant difference in knowledge in the introduction of liquid (p=0.290) and solid foods (p=0.175) between the two groups. On the introduction of liquid and semi-solid food during the first six months of infant's age, differences were observed based on the different types of complementary food: for example, juice, yoghurt, cereals and mashed foods were 55.6%, 56.9%, 81.9% and 74.0%, respectively. Most answers of mothers indicated that sugar and salt should not be added to the infant's complementary food before the age of 6 months based on their knowledge by 83.7% and 90% respectively. Notably, 54.2% of the first group (<6 months) and 58.4% of the second group (>6 months) were aware that healthcare professionals were the most reliable source of information about early complementary feeding (Table 2).

Attitude

Among the first group (<6 months), 57.2% (the total percentage of agree and strongly agree) had a positive attitude towards starting early complementary feeding, while in the second group (>6 months), 67% (the total percentage of disagree and strongly disagree) had a negative attitude towards starting early complementary feeding. Of the first group (<6 months) 26.7% indicated that breast milk alone was not enough to meet the infant's nutritional requirements and 40.0% felt that it did not meet the water requirement as well. In contrast, 74.3% of the second group (>6 months) agreed that it (breast milk) was enough to cover the infant's nutritional requirement and 59.6% of them believed that water should not be introduced before 6 months of age. Similarly, on mothers' knowledge, both groups agreed that sugar and salt should not be added to an infant's complementary food before 6 months by 80.6% and 81.5 %, respectively (Table 3).

Table 1. Socio-demographic characteristics of mothers and infants based on the time of introducing complementary feeding before and after 6 months

Characteristic	*Percentage (%)*‡			*p-value*§
	Total population (n= 771)	*Before 6 months (n= 288)*	*After 6 months (n= 483)*	
Age of mothers				
18-25	11.8	13.9	10.6	0.608
25-30	32.4	31.9	32.7	
30-35	26.5	25.3	27.1	
35-40	20.4	19.8	20.7	
40-45	8.9	9.0	8.9	
Educational level of mother				
Primary school	0.5	0.7	0.4	0.612
Secondary school	2.3	1.4	2.9	
High school	10.9	13.2	9.5	
Bachelor/diploma degree	72.2	71.9	72.5	
Higher degree	14.0	12.8	14.7	
Occupation of mothers				
Employed	45.9	45.1	46.4	0.735
Housewife	54.1	54.9	53.6	
Monthly household income (SAR)†				
< 5000	17.6	22.5	14.7	0.411
6000-10000	38.1	37.2	38.7	
11000-20000	33.1	29.2	35.4	
> 21000	11.2	11.1	11.2	
Age of infants				
6-12 months	36.6	32.6	38.9	0.262
13-18 months	24.4	25.3	23.8	
19-24 months	39.0	42.0	37.3	
Infant gender				
Female	48.6	50.0	47.8	0.856
Male	51.4	50.0	52.2	
No of children in the family				
1	27.5	26.7	27.9	0.667
2	25.0	26.4	24.2	
3	19.3	17.4	20.5	
4	14.1	15.3	13.5	
≥5	14.0	14.2	13.9	
Child order				
1st child	30.2	28.5	31.3	0.964
2nd child	23.0	25.0	21.7	
3rd child	16.7	16.3	16.9	
4th child	16.7	17.0	16.6	
Other	13.4	13.2	13.5	

†SAR = Saudi Riyals; 1 Saudi Riyal = 0.26 $US
‡Percentages were calculated based on total population of each group
§p-value was calculated by chi-square test

Table 2. Comparison of knowledge of mothers regarding early complementary feeding between mothers who introduced complementary feeding before and after 6 months of infant's age

Questions	*Percentage (%)*†			*p-value*‡
	Total population (n= 771)	*Before 6 months (n= 288)*	*After 6 months (n=483)*	
What is the appropriate age to start introducing complementary foods				
<3 months	1.0	2.1	0.4	0.000
3 months	2.6	6.3	0.4	
4 months	17.6	40.9	3.7	
5 months	13.2	27.8	4.6	
≥6 months	65.5	22.9	90.9	
What kind of food can be introduced before 6 months to the infant				
Liquid food				
Yes	92.6	94.4	91.5	0.290
No	7.4	5.6	8.5	
Semi solid food				
Yes	44.9	63.2	34.0	0.000
No	55.1	36.8	66.0	
Solid food				
Yes	2.9	4.5	1.9	0.175
No	97.1	95.5	98.1	
What kind of the following liquids can be introduced during the first 6 months				
Tea				
Yes	5.3	6.3	4.8	0.234
No	94.7	93.7	95.2	
Water				
Yes	79.1	83.3	76.6	0.157
No	20.9	16.7	23.4	
Herbal (infusion)				
Yes	58.6	61.5	56.9	0.487
No	41.4	38.5	43.1	
Bottle formula				
Yes	95.7	95.8	95.7	0.114
No	4.3	4.2	4.3	
Juice				
Yes	38.0	55.6	27.5	0.000
No	62.0	44.4	72.5	

What kind of the following semi-solid foods can be introduced during the first 6 months				
Yogurt				
Yes	42.2	56.9	33.3	0.000
No	57.8	43.1	66.7	
Cereals (Cerelac)				
Yes	65.6	81.9	55.9	0.000
No	34.4	18.1	44.1	
Mashed food (potato, apple...)				
Yes	54.0	74.0	42.0	0.000
No	46.0	26.0	58.0	
Pudding (Jelly)				
Yes	8.4	11.1	6.8	0.060
No	91.6	88.9	93.2	
What is the most reliable source of information regarding early complementary feeding				
Health care professionals	56.8	54.2	58.4	0.342
Social media (WhatsApp, Instagram...etc.)	6.1	6.6	5.8	
Family and friends	23.9	26.4	22.4	
General websites and blogs	10.4	9.7	10.8	
Other	2.9	3.1	2.7	
What is/ are the most important factor/s to promote infant's growth				
Exclusive breastfeeding at least 6 months	73.9	64.9	79.3	0.001
High quality infant formula feeding	12.6	14.9	11.2	
An appropriate practice of complementary feeding	10.0	14.9	7.0	
Vitamins and minerals supplementation	2.3	2.8	2.0	
Other	1.2	2.4	0.4	
What kind of the following spices can be added to complementary foods before 6 months				
Sugar				
Yes	16.3	22.2	12.8	0.000
No	83.7	77.8	87.2	
Salt				
Yes	10.0	15.6	6.6	0.002
no	90.0	84.4	93.4	

†Percentages were calculated based on total population of each group
‡*p*-value was calculated by the chi-square test

Table 3. Comparison of attitude of mothers towards early complementary feeding between mothers who introduced complementary feeding before and after 6 months of infant's age

Questions	*Percentage (%)*†			*p-value*‡
	Total population (n= 771)	*Before 6 months (n= 288)*	*After 6 months (n= 483)*	
Do you think complementary foods can be added before 6 months of an infant's age				
Strongly disagree	17.6	5.9	24.6	0.000
Disagree	31.0	11.8	42.4	
Neutral	24.1	25.0	23.6	
Agree	24.4	50.3	8.9	
Strongly agree	2.9	6.9	0.4	
Breastmilk is not enough to meet the infant's nutritional requirements before 6 months				
Strongly disagree	43.8	29.5	52.4	0.000
Disagree	22.8	24.3	21.9	
Neutral	13.4	19.4	9.7	
Agree	16.5	20.8	13.9	
Strongly agree	3.5	5.9	2.1	
Breast milk is not enough to meet infant's fluid need, which means water should be introduced before 6 months of life				
Strongly disagree	30.7	21.9	36.0	0.000
Disagree	21.8	18.7	23.6	
Neutral	18.3	18.7	18.0	
Agree	21.5	29.9	16.6	
Strongly agree	7.7	10.8	5.8	
What is your attitude towards introducing liquids before 6 months				
Strongly disagree	15.4	4.2	22.2	0.000
Disagree	23.3	11.1	30.6	
Neutral	27.5	23.9	29.6	
Agree	29.1	50.0	16.6	
Strongly agree	4.7	10.8	1.0	

What is your attitude towards introducing semi-solid before 6 months				
Strongly disagree	35.9	20.1	45.3	0.000
Disagree	30.6	26.7	32.9	
Neutral	17.1	23.3	13.5	
Agree	14.3	26.4	7.0	
Strongly agree	2.1	3.5	1.2	
What is your attitude towards adding sugar to the complementary foods before 6 months				
Strongly disagree	59.1	52.1	63.4	0.012
Disagree	21.5	22.9	20.7	
Neutral	12.5	17.7	9.3	
Agree	5.2	5.2	5.2	
Strongly agree	1.7	2.1	1.4	
What is your attitude towards adding salt to the complementary foods before 6 months				
Strongly disagree	60.4	51.7	65.6	0.003
Disagree	21.1	23.3	19.7	
Neutral	11.4	16.7	8.3	
Agree	5.6	6.6	5.0	
Strongly agree	1.6	1.7	1.4	

†Percentages were calculated based on total population of each group
‡*p*-value was calculated by chi-square test

Practices

In regard to practices (Table 4), the results revealed that 37.4% of mothers introduced complementary food to their infants before the age of 6 months. Among mothers of the first group (<6 months), the majority introduced complementary food to their infants in the fourth or fifth month of age (47.5% and 45.5%, respectively). Of the reasons given, 83.3% of them stated that the main factor that drove them to initiate early complementary feeding was that they felt the baby was old enough to receive complementary foods. Among all the mothers surveyed, 55.9% gave a combination of breast milk and infants formula during the first 6 months of age. Of the most common two types of food given to the baby before 6 months, 83.0% favoured liquids and 72.9% preferred mashed foods. Vegetables and fruits, carbohydrate foods, and dairy products were the most likely food groups given to the infant before they reached 6 months of age by 85.8%, 61.1% and 54.9% respectively. On the other hand, sugar was more likely to be added than salt. The results showed 20.1% of mothers added sugar while 17.4% added salt (Table 4).

Scoring and interrelationship between knowledge, attitude and practice

As summarised in Table 5, 62.5% of the total study population appeared to possess a medium level of knowledge. The majority of both groups, viz. <6 months and >6 months, had medium knowledge with percentages of 76.0% and 54.4%, respectively. However, there was an obvious difference for those with high knowledge with only 10.0% for the first group of mothers (<6 months) showing this feature and 43.7% for the second group (>6 months).

As for attitude, the results indicated that the majority of all the mothers (55.2%) had a higher tendency towards neutral attitude towards the early introduction of complementary feeding. However, 62.5% of the mothers in the first group (<6 months) showed a neutral attitude towards initiating early complementary feeding. It was observed that 68.3% of the second group (>6 months) believed that complementary feeding should be started at the age of 6 months or later. This meant that they had a negative attitude towards early complementary feeding.

Overall, scores for practices showed that 62.6% of the total population surveyed were good while 37.4 % had poor practices. Regarding the association between the 3 aspects (KAP) among the total population surveyed, results showed that knowledge and attitude had significantly correlated to practice (p-value=0.000) (Table 5).

DISCUSSION

This KAP study aimed to examine the current state of early complementary feeding among Saudi mothers in Riyadh. The most important result was that 37.4% of the 771 mothers who were studied had introduced early complementary feeding to their infants. This figure was lower compared reported in a study done in Tabuk which showed that 62.5% of mothers introduced complementary feeding before the child reached 4 months of age (Alzaheb, 2016). The reasons for these findings may be due to their children getting hungry, the perception that it was a good age to start complementary feeding besides other factors. Another study conducted in Saudi Arabia that included five different regions (Northern, Southern, Middle, Eastern and Western), reported that 83% of infants were introduced to early complementary feeding (Adam & Osama, 2019).

In this study, higher percentages of medium knowledge, neutral attitude

Table 4. Practice of mothers regarding early complementary feeding among mothers who introduced complementary feeding before 6 months of infant's age (n=288)

Questions	*Percentage (%)*†
When did you initiate complementary food to your child?	
<3 months	3.5
3 months	3.5
4 months	47.5
5 months	45.5
In case you started giving early complementary food to your baby, what was/were the reason/s that drove you?	
Baby is hungry	
Yes	43.7
No	56.3
The baby is old enough	
Yes	83.3
No	16.7
Poor weight gain	
Yes	30.9
No	69.1
Maternal illness	
Yes	6.3
No	93.7
What type of milk has been introduced during the first 6 months?	
Breast milk (breastfeeding or expressed breast milk)	23.3
Combined breast milk and infant formula	55.9
Infant formula only	20.8
What was the texture and characteristics of complementary foods introduced before 6 months?	
Soup/liquid	
Yes	83.0
No	17.0
Puree/ mashed food	
Yes	72.9
No	27.1
Chopped food/solid	
Yes	8.3
No	91.7
What is/are food groups contained in your child's diet before 6 months?	
Carbohydrate (e.g., rice, bread, cereal)	
Yes	61.1
No	38.9
Protein (e.g., egg, chicken, liver, beans, lentils)	
Yes	14.2
No	85.8
Fat (e.g., vegetable oil, butter, cheese)	
Yes	7.3
No	92.7
Vegetables and fruits	
Yes	85.8
No	14.2
Dairy products	
Yes	54.9
No	45.1
Did you add any sugar or salt to complementary food before 6 months?	
Sugar	
Yes	20.1
No	79.9
Salt	
Yes	17.4
No	82.6

†Percentages were calculated based on population of mothers who introduced early complementary feeding (n= 288)

Table 5. Comparison of scoring of knowledge, attitude and practice of mothers towards early complementary feeding between mothers who introduced complementary feeding before and after 6 months of infant's age

Aspects	*Percentage (%)*†			*p-value*‡
	Total population (n= 771)	*Before 6 months (n= 288)*	*After 6 months (n= 483)*	
Knowledge				
Low	6.3	14.0	2.0	Versus Attitude= 0.000
Medium	62.5	76.0	54.4	Versus Practice= 0.000
High	31.0	10.0	43.7	
Attitude				
Negative	13.6	14.5	7.25	Versus Knowledge= 0.000
Neutral	55.2	62.5	24.4	Versus Practice= 0.000
Positive	31.0	23.0	68.3	
Practice				
Poor	37.4	100.0	0.0	Versus Knowledge= 0.000
Good	62.6	0.0	100.0	Versus Attitude= 0.000

†Percentages were calculated based on total population of each group
‡*p*-value testing the interrelationship between the knowledge, attitude and practice calculated by chi-square test

and poor practices regarding early complementary feeding were observed among the group of mothers who introduced early complementary feeding to their infants compared to the mothers who had initiated complementary feeding after 6 month of age. In addition, knowledge and attitude of the mothers significantly influenced their practices in relation to early complementary feeding.

Azzeh (2017) found that the practice of complementary feeding was significantly associated with the job patterns of the mothers as well as the educational level of the parents. In contrast, there was no significant association between education and the age of mothers with the time of the introduction of complementary feeding in Kosova (Berisha *et al.*, 2017). The finding from the Kosova study matches the result of this study, which demonstrated no significant difference between starting early or on time complementary feeding in terms of socio-demographic characteristics of mothers in both groups. This might be related to the differences in the level of knowledge. The appropriate age for the introduction of complementary feeding was known among 65.5% of the current study. Similarly, studies from Ethiopia, Abha, and India revealed that 60.3%, 89.3% and 92.5% respectively had the right knowledge about starting timely complementary feeding (Reda, Teferra & Gebregziabher, 2019; Khattab, 2000; Jain, Thapar & Gupta, 2018). As with Ethiopia, the educational level of the husbands allowed them to support their wives to delay early weaning for better health of the child. In Abha and India, the higher educational level of mothers positively influenced their knowledge.

As for knowledge, 56.8% stated that the most reliable source of information about complementary feeding were health care professionals. A study conducted in Erbil city showed mothers learnt about infant feeding from physicians (41.6%) and from nurses (54.7%), at the primary healthcare centers (Al-Azzawi, Hussein & Shaker, 2012). A study conducted in Saudi Arabia showed that mothers learnt about breastfeeding from medical personnel (44.9%) and from their relatives (26.8%) (Al-Jassir *et al*., 2006). Thus, the role of health care as knowledge providers should be seriously promoted in order to ensure that correct and adequate information on breast-feeding practices is provided to mothers.

In regard to attitude and practices, 83.3% of mothers in the current study and 26.6% in a previous study conducted in Tabouk showed that complementary feeding was initiated when mothers thought that the baby was old enough to receive complementary foods (Alzaheb, 2016). A study in Abha found that 63.1% of mothers believed that water and fluids were needed for the infant during the first 4 months of age (Khattab, 2000). However, only 29.2% of the current study population believed that water and fluids were needed in addition to breast milk before the age of 6 months. The majority of mothers (66.6%) in a study conducted in Nigeria added salt to the meals of their infants (Olatona *et al*., 2017), whereas only 17.4% of mothers did so before 6 months in our study. This disparity in practices may relate to the low levels of knowledge and practice among mothers in Nigeria compared with the current study where the knowledge levels of mothers were higher. Our study and two other previous studies carried out in Tabouk and another in Mecca seemed to have comparable results regarding common types of food that were given before 6 months of age such as, baby cereals, vegetables and fruits (Alzaheb, 2016; Azzeh, 2017).

In terms of the limitations of this study, it is possible that data collection through online questionnaire could lead some participants to misunderstand some of the questions. However, the questionnaire was tested and readjusted to ensure ease of understanding before it was used. As convenient sampling technique was used, results of this study should not be generalised.

CONCLUSION

By initiating complementary feeding to their infants before 6 months of age, more than one-third of Saudi mothers who participated in the study were shown to have not followed the relevant WHO recommendation on this matter. As clearly demonstrated, a significant association existed between various KAP aspects in the introduction of early complementary feeding. The knowledge of mothers who practised early complementary feeding had an impact on their attitude and practice as well. Therefore, health care providers should focus on educating mothers to correct their understanding of early complementary feeding and its consequences. It is recommended that further research be undertaken in the different regions of Saudi Arabia in order to obtain better knowledge of the current status of infant feeding among Saudi mothers.

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Authors' contributions

AA, DA, GA., SA and YA, drafted the article; NB critically revised the article. All authors made a substantial contribution to the design of the work and in the acquisition, analysis and interpretation of data. All authors approved the version that was submitted for publication and participated sufficiently in the work to take public responsibility for appropriate portions of the content.

Conflict of Interests

The authors declared that there is no conflict of interest.

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Equations to predict height and weight in Asian-Chinese adults

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ABSTRACT

Introduction: Height and weight measurements are required for the assessment of nutritional status. However, it is difficult to measure these parameters in non-ambulatory persons. Hence, simple predictive equations that estimate these measurements using various anthropometric measurements are necessary. **Methods:** A total of 441 Asian-Chinese adults (174 males, median age = 32.5, IQR: 27.8 years; 267 females, median age = 34.6, IQR: 28.5 years) were used to build height and weight sex-specific prediction equations. An additional 111 Asian-Chinese adults (44 males, median age = 31.1, IQR: 25.0 years; 67 females, median age = 30.6, IQR: 25.6 years) were used to validate the newly developed prediction equations. **Results:** The best predictive model for height included arm length, knee height measurements and age (R^2 = 0.70, standard error of estimate [SEE] = 3.38 for males; R^2 = 0.71, SEE = 3.14 for females). The best weight predictive model included age, arm circumference and waist circumference (R^2 = 0.79, SEE = 4.66 for males; R^2 = 0.78, SEE = 4.38 for females). The new predictive models for height and weight have non-significant prediction biases as compared to the Cereda *et al.* (2010) and Ross equations, respectively. **Conclusion:** Height and weight predictive equations with a higher degree of accuracy have been developed for Asian Chinese adults.

Keywords: Height, weight, prediction equations, anthropometry, simple

INTRODUCTION

Height and weight are significant clinical measures that are necessary to assess the health and nutritional status of an individual (Sah, Kumar & Bhaskar, 2013). Height and weight measurements are used to calculate the body mass index (BMI), which is a rapid and easy method that is widely used to assess the health status of an individual. The BMI is an assessment of body weight and its calculation is beneficial (Hall & Cole, 2006). Based on the BMI, individuals may be categorised as underweight, normal weight, overweight and obese. Furthermore, drug dosages are determined based on the BMI and body surface area calculation which is calculated from height and weight of an individual (Chittawatanarat *et al.*, 2012; Sah *et al.*, 2013).

However, the measurements of height and weight are not always easily obtained especially in those who are

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not ambulatory and are incapable of upright posture. To date, various indirect methods have been developed to estimate height and weight from measuring body segments. Chumlea *et al.* (1988) were one of the first to develop predictive equations for height and weight estimations using anthropometric measurements in an elderly population. Chumlea's model for predicting height was developed in Hispanic and non-Hispanic Whites, and Blacks, in the United States using knee height. After that, various other models have been developed to predict height and weight using anthropometric measurements in various populations (Agarwal, Zaidi & Agarwal, 2015; Cereda, Bertoli & Battezzati, 2010; Chittawatanarat *et al.*, 2012; Sah *et al.*, 2013).

The generalisation of such equations is questionable as anthropometric measurements are ethnic- and age-specific. For example, Chinese are known to have relatively shorter legs as compared to Caucasians of the same height (Eveleth *et al.*, 1976). As there is no formula to predict height and weight in Asian-Chinese adults, the objective of this study was to 1) develop predictive models for height and weight in Asian-Chinese adults and 2) to compare the predictive performance of the models with two other models.

MATERIALS AND METHODS

Study design and participants

The predictive equations were developed and evaluated for validity using data from a cross-sectional study conducted at the Clinical Nutrition Research Centre (CNRC), Singapore, between June 17, 2014, and October 20, 2017. The inclusion criteria included females who were not pregnant, and males and females without a diagnosis of any major diseases, such as diabetes and hypertension, and not on long-term medication. Athletes and fit individuals were not excluded. Participants were recruited through advertisements that were placed around the National University of Singapore campus, public area, and on the CNRC website. A total of 441 of the enrolled participants (174 males, age range 21-74; 267 females, age range 21-74) were used to develop the predictive equations. An additional 111 (44 males, age range 22-63; 67 females, age range 21-64) who were enrolled under the same study were used to evaluate the validity of the developed prediction equations. The National Healthcare Group Domain Specific Review Board (NHG DSRB, Reference Number: 2013/00783), Singapore, provided ethical approval for the protocols of the cross-sectional study. The trial registration number was ACTRN12614000643673. All participants provided written and informed consent prior to the commencement of the study.

Anthropometric measurements

Anthropometric measurements were taken in a fasting state following standard protocols (Lohman, Roche & Martorell, 1988). As this study was secondary to another primary study in which fasting blood sample was collected, anthropometric measurements were also done in the fasted state. Weight (in kg) was measured to the nearest 0.1 kg in light clothing without footwear using an electronic scale (Seca 763 digital scale, Birmingham, United Kingdom) and height (in cm) was measured using a stadiometer (Seca 763 digital scale, Birmingham, United Kingdom) to the nearest 0.1 cm. Waist circumference (WC) and arm relaxed girth (arm circumference, AC) was measured using a standard non-elastic measuring tape (Lufkin W606PM). WC was taken at the smallest reading above the umbilicus or navel and below the xiphoid process. AC was taken at the level of the midacromiale radiale when the participant assumed a relaxed standing position with the arms hanging by the sides. Tibiale laterale (knee height) was taken as the vertical distance from the tibiale laterale site to the standing height using a segmometer. Foot length was taken as the linear distance between the coronal planes of the Pternion and Akropodion using a caliper scale (Element14, Singapore). All of these measures were done on the right sides of the body.

All anthropometric measurements were done in duplicate. The quality of the measurements was assessed and a third measurement was taken if the deviation between the first two measurements was > 2%. The final measurement value used was the average of the duplicate or triplicate measurements. All measurements were taken by research staff who were trained by one of the principle investigating officers of the study.

Statistical analysis

Sex-specific equations were explored using easily obtainable anthropometric measurements to predict height and weight, separately. Arm length, foot length, knee height and age were explored for predicting height while AC, WC, hip circumference (HC) and age were assessed for predicting weight.

Model selection was done using stepwise regression with the Akaike Information Criterion (AIC) (Shmueli, 2010). The AIC is a measure that is used to compare the fit of related models for a given dataset. The smaller the value of AIC, the better the model fits the data, hence the model with the smallest AIC was chosen as the initial model for predicting height and weight. The initial model was further modified to ensure that the predictive model was simple with easily obtainable measurements. Predictive equations with a maximum of two anthropometric measurements were deemed to be simple. The model with the highest predicted R^2, adjusted R^2 and lowest standard error of estimate (SEE) was chosen as the final predictive model (Table 2A and 2B). The predicted R^2 is a form of cross-validation that indicates the predictive performance of the models in a new dataset that has a different set of participants, which was not included in the model building set. The higher predicted R^2 was one indication of better model performance. The adjusted R^2, as the name suggests, is an adjusted form of R^2 (correlation coefficient of determination), which indicates how well the model fits the data. The higher the value the better the model fit (Ho, 2006).

The predictive performance of the newly chosen predictive models was cross-validated in the independent dataset (*N* = 111, males = 44, females = 67) and also compared with the performance of the Cereda *et al.* model (Cereda *et al.*, 2010) for height, and the Ross Laboratories model (Melo *et al.*, 2014) for weight. The prediction bias, mean absolute percentage error and root mean squared error (RMSE) values of the chosen prediction models were used to compare the predictive performance of the newly developed models. The prediction bias referred to the mean difference between the observed and predicted values. The smaller the difference the better the (predictive) model predicts. RMSE amplifies errors between the predicted and observed values and helps in determining the predictive performance of the model (Rativa, Fernandes & Roque, 2018). The formula for the RMSE is as follows:

$$RMSE = \sqrt{\frac{1}{n}\sum(observed - predicted)^2}$$

Mean absolute percentage error was calculated using the formula as follows:
Mean absolute percentage error =

$$\left\{\frac{1}{n}\sum\left(\frac{|observed - predicted|}{observed}\right)\right\} \times 100\%$$

The predictive models for both height and weight were also evaluated for bias using the paired sample *t* test and deviation from the line of identity (observed graphically) method. For the latter method, the predicted values (height or weight) were used as the dependent variable and the actual measured values (height or weight) were the independent variable. The Mann-Whitney test was used to test for significant differences in the characteristics of the participants in the model building and validation dataset.

All statistical analyses in this study were done using SPSS version 24 (IBM Corp., Armonk, NY) and Statistical software R (R Studio Inc., Boston, MA). Data were reported as mean±standard deviation (SD) or median and interquartile range where appropriate, and all statistical tests in this study were significant at $p<0.05$.

RESULTS

Table 1 summarizes the characteristics of the participants who were recruited into the study. There were no statistically significant differences in the participant characteristics between the model validation and model building datasets ($p>0.05$). Prediction models for height and weight were developed separately for each sex using this dataset.

The model with the smallest AIC for predicting height included all the variables under consideration, i.e. arm length, knee height, foot length and age. Among them, arm length had the highest standardised coefficient values in linear regression for both sexes. Hence, it was seen to be highly effective in the height-prediction model. Hence, two other models with either knee height or foot (but not both at the same time) were compared while keeping the other variables unchanged. The predicted R^2, adjusted R^2 and SEE of the subsequent models were compared (Table 2A). The

Table 1. Description of the study participants used in model building (n=441) and validation dataset (n=111)

Characteristics[†]	*Model building dataset*				*Validation dataset*			
	Females (n=267)		*Males (n=174)*		*Females (n=67)*		*Males (n=44)*	
	Median	*Interquartile range*	*Median*	*Interquartile range*	*Median*	*Interquartile range*	*Median*	*Interquartile range*
Age (years)	34.6	28.5	32.5	27.8	30.6	25.6	31.1	25.0
Waist circumference (cm)	69.3	9.9	77.7	11.0	68.5	9.9	80.5	13.7
Height (cm)	159.9	7.8	171.5	8.1	159.0	6.8	170.6	9.7
Arm circumference (cm)	24.8	4.8	28.9	4.8	25.7	4.7	29.5	4.2
Knee height (cm)	40.6	3.9	44.1	4.7	39.7	4.0	44.4	6.3
Foot length (cm)	22.7	1.7	25.0	1.9	22.5	1.9	24.9	1.9
Hip circumference (cm)	91.1	8.0	92.7	8.6	90.4	9.6	94.5	9.1

[†]There were no significant differences ($p>0.05$) in the characteristics between model building and validation dataset using the Mann-Whitney test.

Table 2A. Details of the model selection process of height for both sexes using the model building dataset (*n*=441)

Sex	*Models for height*	*Predicted R^2*	*Adjusted R^2*	*SEE*
Males	Arm length, knee height, foot, age	0.69	0.71	3.32
	Arm length, knee height, age†	0.69	0.70	3.38
	Arm length, foot, age	0.66	0.67	3.51
Females	Arm length, knee height, foot, age	0.75	0.76	2.87
	Arm length, knee height, age†	0.70	0.71	3.14
	Arm length, foot, age	0.70	0.71	3.14

†These are the final predictive models that were chosen

model with arm length, knee height and age had the highest predicted R^2, adjusted R^2 and smallest SEE as compared to the initial model that was selected using the AIC procedure in the males (Table 2A). Hence, the height-prediction model for the males included arm length, knee height and age. The model for females showed no significant difference in the performance of the predictive equations with knee height or foot length (Table 2A). As such, the model for males was usable for females as well.

The sex-specific equations that have been developed for predicting height are as follows:

Height (cm) for males =
64.30+[2.19×arm length (in cm)]
+[0.83×knee height (in cm)]
+[0.02×age (in years)]

Height (cm) for females =
67.83+[2.08×arm length (in cm)]
+[0.84×knee height (in cm)]
-[0.06×age (in years)]

The same AIC stepwise regression method was used to develop sex-specific predictive models for weight. The weight-predictive model with the smallest AIC for males included HC, AC and WC measurements, and age. The initial model was further compared with models that either had WC coupled with or without AC instead of HC to obtain a simple predictive model with easily measurable variables (Table 2B).

In males, the model with WC, AC and age was seen to perform similar to the model with HC instead of WC (Table 2B). Hence, the model with WC was chosen as the weight-prediction model for males.

Table 2B. Details of the model selection process of weight for both sexes using the model building dataset (*n*=441)

Sex	*Models for weight*	*Predicted R^2*	*Adjusted R^2*	*SEE*
Males	Hip circumference, arm circumference, waist circumference, age	0.86	0.87	3.64
	Age, arm circumference, waist circumference†	0.78	0.79	4.66
	Age, arm circumference, hip circumference	0.84	0.84	4.00
Females	Hip circumference, waist circumference, age	0.85	0.86	3.54
	Arm circumference, waist circumference, age†	0.77	0.78	4.38
	Waist circumference, age	0.75	0.76	4.58

†These are the final prediction models that were chosen

Table 3A. Evaluation of the validity of the newly developed prediction equations for height with Cereda *et al.* predictive equations using 111 datasets from 44 males and 67 females

Sex	*Model*	*Prediction bias* (cm)	*Mean absolute percentage error* (%)	*RMSE*† (cm)
Males	Arm length, knee height, age‡	0.00±2.77	1.33±0.92	2.74
	Knee height, age, sex§	-14.38±6.20***	8.36±3.61	15.63
Females	Arm length, knee height, age‡	0.52±3.00	1.51±1.17	3.02
	Knee height, age, sex§	-13.84±4.75***	8.70±2.94	14.62

†RMSE: root mean squared error
‡These are the newly developed equations
§Equations developed by Cereda *et al.* (Cereda *et al.*, 2010)
****p*<0.001

For females, the weight-prediction model with the smallest AIC included both HC and WC along with age. Again models with WC but with or without AC were compared to obtain the model with the highest predicted R^2, adjusted R^2 and low SEE (Table 2B).

The sex-specific equations that have been developed for predicting weight are as follows:
Weight (kg) for males =
-16.75-[0.14×age (in years)]
+[0.69×arm circumference (in cm)]
+[0.89×waist circumference (in cm)]

Weight (kg) for females =
-12.86-[0.15×age (in years)]
+[0.69×arm circumference (in cm)]
+[0.81×waist circumference (in cm)]

The performance of the height- and weight-prediction equations and the various comparative equations are summarised in Table 3A and 3B. Unlike the model by Cereda *et al.* (2010), the prediction bias of the newly developed height-prediction models was not significant for both the sexes. Furthermore, the mean absolute percentage error and RMSE were <2% and <3.0 cm, respectively, for both sexes (Table 3A).

However, the mean absolute percentage error and RMSE of the model by Cereda *et al.* (2010) were about 9% and 16 cm, respectively, for both sexes (Table 3A). Therefore, the newly developed height-prediction models in this study predicted height better than the model by Cereda *et al.* (2010).

As for the weight-prediction models, the newly developed models had non-significant prediction bias with mean absolute percentage error of <7% and RMSE of <5 kg for both sexes (Table 3B). By contrast, the mean absolute percentage error and RMSE were about 16% and 11 kg, respectively, for white people, and, 30% and 17 kg, respectively, for black people when using the Ross Laboratories model (Melo *et al.*, 2014) (Table 3B). Therefore, the newly developed weight-prediction models predicted better than Ross Laboratories model (Melo *et al.*, 2014) for both black and white men and women.

The performance of the height- and weight-prediction models was examined by plotting the predicted versus the actual measured values (Figure 1 and 2). The bold straight lines (line of

Table 3B. Evaluation of the validity of the newly developed prediction equations for weight with Ross's predictive equations using 111 datasets from 44 males and 67 females

Sex	*Model*	*Prediction bias (kg)*	*Mean absolute percentage error (%)*	*RMSE[a] (kg)*
Males	age, arm circumference, waist circumference[b]	-0.25±4.67	5.48±4.23	4.62
	knee height, arm circumference (Ross, white men)[c]	-9.35 ±6.44***	13.36±8.29	11.31
	knee height, arm circumference (Ross, black men)[c]	-12.79±6.32***	17.93±8.49	14.23
Females	arm circumference, waist circumference, age[b]	0.53±4.53	6.46±6.27	4.53
	knee height, arm circumference (Ross, white female)[c]	-8.79±5.32***	16.33±8.97	10.25
	knee height, arm circumference (Ross, black female)[c]	-16.02±5.17***	29.63±9.75	16.82

***P<0.001; [a] RMSE: root mean squared error; [b] The newly developed equations; [c] Equations developed by Ross (Melo *et al.*, 2014).

identity) in Figure 1 and 2 indicate the line of perfect prediction (R^2 = 1). The predicted and observed values for height and weight using the newly developed equations fell on or near the line of identity for both sexes (Figure 1 and 2). However, for the other reference models, the predicted and observed values for height and weight fell below the line of identity. It should be noted that the newly developed height-prediction models slightly overestimate for shorter people and slightly underestimate for taller people (Figure 1 and 2).

DISCUSSION

Height and weight are important anthropometric parameters that need to

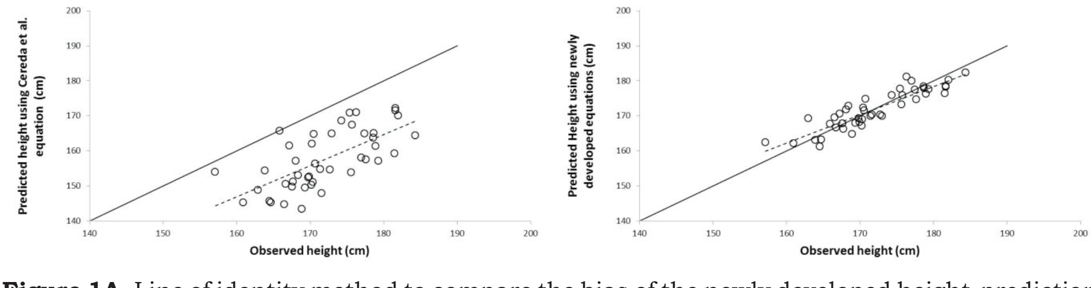

Figure 1A. Line of identity method to compare the bias of the newly developed height-prediction models in males with the Cereda *et al.* model. This was done using 111 datasets from 44 males and 67 females. The solid black line represents the line of perfect prediction while the dotted line is the best fitted line

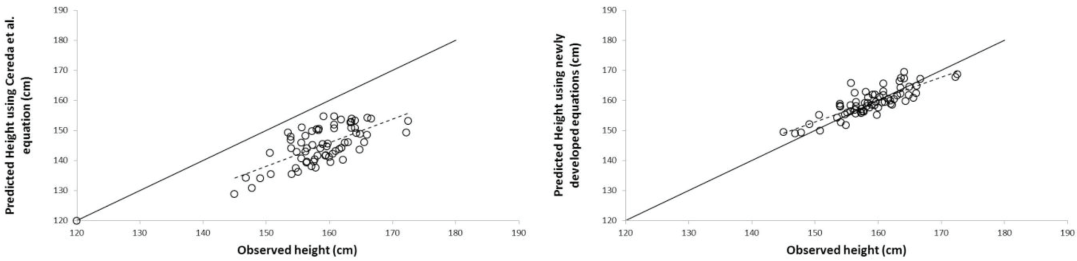

Figure 1B. Line of identity method to compare the bias of the newly developed height-prediction models in females with the Cereda *et al.* model. This was done using 111 datasets from 44 males and 67 females. The solid black line represents the line of perfect prediction while the dotted line is the best fitted line

be evaluated to determine the nutritional status and drug dosage of an individual. There have been predictive equations that have been developed for various populations because anthropometric measurements are ethnicity- and age-specific (Eveleth *et al.*, 1976). In this study, predictive equations for Asian-Chinese adults were developed. The proposed equations serve to perform screening for over- and under-nutrition in individuals when the direct measurements of height and weight are either impossible or impracticable, i.e. in non-ambulatory people.

Knee height, arm length, foot length and age were the variables that were considered for developing height-prediction model. All the three anthropometric variables that were considered had a linear relationship with height. Knee height is one of the commonest anthropometric variables used as a proxy indicator to standing height, as it is independent of age and does not appear to decrease over time. It can be measured while seated or lying down (Hickson & Frost, 2003). Similarly, foot length was considered as it has been known through the work by Rutishauser (Rutishauser, 1968) that foot length has a strong correlation with the long bones in the body (Patel, Shah & Patel, 2007). As shown in the current study, the model with knee height and arm length had a higher predictive R^2 and lower SEE as compared to a model with foot length. Therefore, knee height, arm length, and age were used to predict height.

HC, AC, WC, and age were the anthropometric variables that were considered for developing the weight-prediction model. All the variables that were considered had a linear relationship with weight. The models with HC, AC, WC, and age had the highest predicted R^2 and lowest SEE for males. However, models with only two anthropometric measurements were considered to be simple and practical. Having to measure multiple anthropometric measurements so as to predict height/weight will not be practical or efficient since it would have defeated the purpose of developing a predictive model as body length could be measured directly instead. Though the models with HC, WC and age had the highest predicted R^2 and smallest SEE for the females, models without HC were compared in both sexes.

As the predictive models are for those who are not able to step on the scale independently, anthropometric measurements that could be obtained with ease from those lying supine are necessary. For this reason, WC was preferred to HC as the former could be obtained by lifting an individual to sit on a wheelchair and obtaining the measurement. Due to this reason,

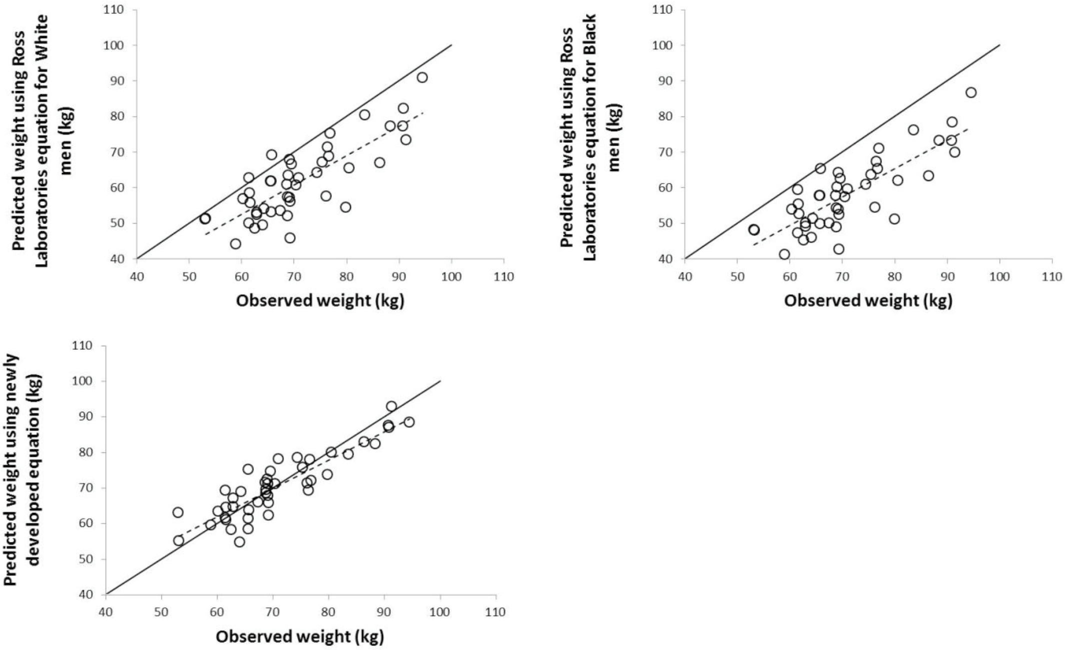

Figure 2A. Line of identity method to compare the bias of the newly developed weight-prediction models in males with the Ross model. This was done using 111 datasets from 44 males and 67 females. The solid black line represents the line of perfect prediction while the dotted line is the best fitted line

models without HC were developed and compared with each sex.

The predicted R^2 of weight-prediction models with AC, WC and age differed from the models that included HC by 0.08 in males and females. The similarity in performance of models with and without HC but with WC could be attributed to the fact that Asians have a tendency for abdominal adiposity (Lim *et al.*, 2011; Wulan, Westerterp & Plasqui, 2010). Hence, the inclusion of WC and AC was still able to compensate for the exclusion of HC in the model.

Asians have different body morphology compared to Caucasians (Eveleth *et al.*, 1976). Hence, the predictive equations developed in Caucasian populations cannot be generalised to Asians. This has been shown in this study where the height and weight prediction equations by Cereda *et al.* (2010) and the Ross Laboratories model (Melo *et al.*, 2014) respectively, significantly underestimated the height and weight values ($p<0.001$) for both sexes (Table 3A and 3B). Furthermore, the line of identity in Figures 1 and 2 illustrate that the predicted values using the model by Cereda *et al.* (2010) or Ross Laboratories (Melo *et al.*, 2014) were below the line of perfect prediction (the bold line in Figures 1 and 2); this again illustrates the underestimation made when using these models for predicting height and weight, respectively.

We acknowledge the limitations in this study. The study was done on healthy subjects, so the generalizability of the model in impaired groups such as individuals with extreme skeletal deformities and marked muscle hypotrophy is limited. Secondly, the study was done on Asian-Chinese

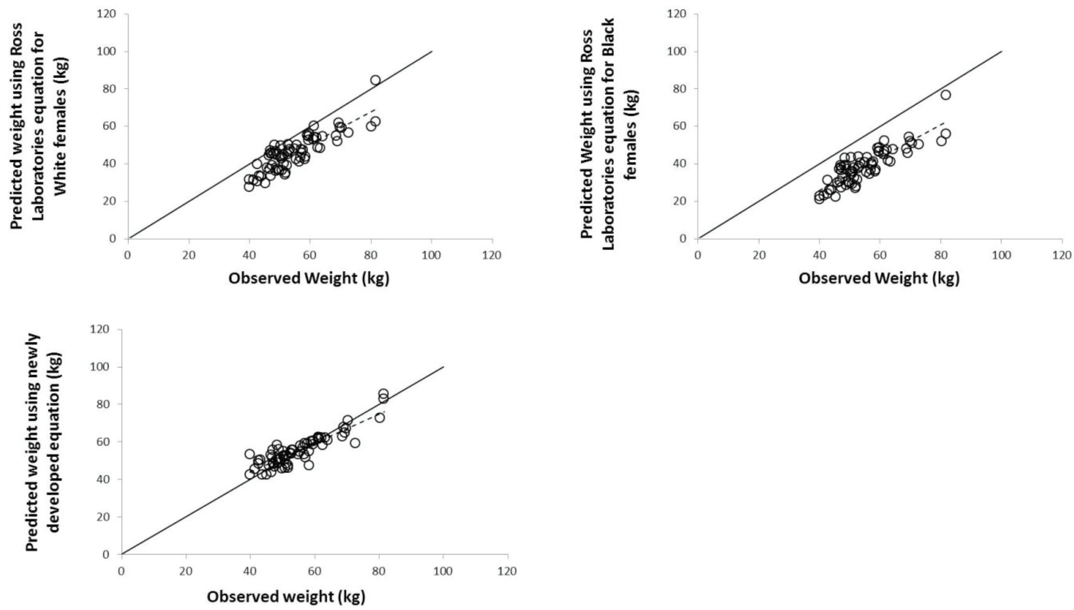

Figure 2B. Line of identity method to compare the bias of the newly developed weight-prediction models in females with the Ross model. This was done using 111 datasets from 44 males and 67 females. The solid black line represents the line of perfect prediction while the dotted line is the best fitted line

living in Singapore. Further research is warranted to validate the applicability of the new equations in a larger number of Chinese adults both living in China and elsewhere. However, the use of a large population to develop the predictive equations is the strength of this study. It should be emphasised that this is the first attempt to predict height and weight in Asian-Chinese adults using anthropometric measurements.

CONCLUSION

Height and weight measurements are necessary for assessing the health status of an individual but they are not easily obtainable in those who are unable to stand erect or remain supine. Hence, equations to predict height and weight that are specific for Asian-Chinese have been developed in this study. The accuracy of the new developed equations to predict height and weight are better than the predictive equations by Cereda *et al.* (2010) and Ross Laboratories model (Melo *et al.*, 2014) respectively.

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Authors' contributions

CJH, principal investigator, conceptualised and designed the study, interpreted the results, assisted in drafting the manuscript and reviewed the manuscript; SP, performed statistical analysis, interpreted the results, assisted in drafting the manuscript; XB, conducted the study, interpreted the results, assisted in drafting the manuscript and reviewed the manuscript.

Conflict of interest

Authors declare no conflict of interest.

List of abbreviations

AC: arm circumference; AIC: Akaike Information Criterion; HC: hip circumference; RMSE: root mean squared error; WC: waist circumference

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Challenges in a refeeding programme: case report of an *Orang Asli* boy at household level

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ABSTRACT

Introduction: The refeeding programme in government hospitals is aimed at improving the nutritional status of malnourished children with weight-for-height z-score (WHZ) below -2.0, using special therapeutic food. However, there is a lack of data on the nutritional status of indigenous *(Orang Asli)* children when they return to the community after hospital discharge. **Case presentation:** A 3-year-old Temiar boy residing in a tribal village in Hulu Perak was visited to determine his nutritional status following discharge from a refeeding programme in a government hospital. He was admitted to the hospital with a weight of 10.0 kg, height of 85.5 cm and WHZ of -2.09. The boy was later discharged weighing 11.0 kg, and with height unchanged at 85.5 cm and WHZ of -0.87. During our visit to the child's home three months after discharge, his weight was 9.5 kg, height 86.0 cm, and WHZ –2.91. **Discussion:** The management of the case in the hospital was based on the Malnourished *Orang Asli* Protocols of the hospital. Household food insecurity, feeding and care practices, unhealthy household environment and the lack of communication between hospital and community health services were all identified as risk factors for malnutrition. **Conclusion:** The recurrence of malnutrition in this child, after successful improvement during hospital stay, highlights the importance of identifying factors that may affect nutritional status after hospital discharge. This knowledge will be beneficial in planning specific interventions, especially for *Orang Asli* children, living in remote villages.

Keywords: Child, indigenous people, malnutrition, refeeding programme

INTRODUCTION

Malnutrition remains high among indigenous *Orang Asli* children as shown by recent findings of Wong *et al.* (2018), where prevalence of stunting, underweight, wasting, and thinness among *Orang Asli* children <5 years were 64%, 49%, 14%, and 12%, respectively. Malnourished *Orang Asli* children were also at a higher risk of dying before reaching 5 years of age (Wong & Hussain Imam, 2008). It is recommended that

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Orang Asli children presenting with a z-score of weight-for-height (WHZ) of <-2.00 should be brought to a designated health centre/hospital for refeeding (HRPB, 2009). Refeeding usually involves providing special therapeutic food, which consists mostly of ready-to-use therapeutic food or milk-based diets of 75 kcal/100ml (F75) and 100 kcal/100ml (F100). Post-discharge, these children should receive optimal care to ensure good nutritional status. However, due to poverty and lack of accessibility to health services, malnutrition still recurs among these children, particularly those residing in the interior rural areas (Amar Singh, 2008). As there is little data that is available on the outcomes of refeeding programmes in Malaysia, we wish to highlight the challenges faced during and after refeeding programmes for the *Orang Asli* community in this case report.

CASE PRESENTATION

A 3-year old Temiar boy residing in a tribal village in Hulu Perak was visited to determine his nutritional status following his discharge from a refeeding programme in a government hospital. The distance between the hospital and the village was 80 km and a single journey took approximately an hour and 40 minutes via different modes of transportation (including one hour by car to the jetty on tarred road, 30 minutes by boat and ten minutes by motorcycle from the jetty on gravel and cement-based road). The village was under the operational area of *Rancangan Pengumpulan Semula* (RPS) or Resettlement Scheme and the nearest static health clinic (*Klinik Kesihatan*) was located 3.5 km from the child's house.

The boy was the third-born child among four siblings. There was no information available on his antenatal history from the clinic records as his mother did not seek any antenatal care from the clinic. Neither the birth weight nor the birth length of the child was recorded as this was a home delivery.

The child was breastfed up to two years after his birth and his mother stopped breastfeeding him when she became pregnant with her next child. Complementary feeding was started at six months of age with a commercial cereal-based infant food instead of home-made porridge. His mother had chosen the commercial cereal-based food due to its soft texture and said that 'the child liked it'.

The family house was entirely built of wood, with no rooms but had a single partition that divided the living and kitchen areas. A gravity feed system, which used gravitational force to draw clean water from higher to lower ground level areas, was used as the main source of water for cooking and laundry. There was no built-in toilet in the house and all sanitary activity and defecation were performed out in the open area, such as at the river or nearby areas.

The mother was a 43-year-old housewife, who weighed 40.9 kg, was 152.8 cm in height and had a body mass index (BMI) of 17.5 kg/m^2. She was classified as underweight (BMI was <18.5 kg/m^2) as per the current World Health Organization (WHO) classification of BMI (WHO, 1998). The child's father worked as a rubber tapper with a monthly income of RM400, or RM66.70 per capita which is below the hardcore poverty line of RM539 per household or RM140 per capita for rural areas of Perak (DOSM, 2016). The father was, however, not measured due to his absence during the visit.

The child was admitted for the first time to the hospital's refeeding programme on 10th August 2017 (weight 10.0 kg, height 85.5 cm, WHZ -2.09). At discharge on 15th August 2017, he had the following parameters: weight

11.0 kg, height 85.5 cm, WHZ -0.87. During our visit to the child's home, three months after his discharge, his weight, height and WHZ were 9.5 kg, 86.0 cm, -2.91 respectively. His mid upper arm circumference reading was 111 mm, and he showed signs of kwashiorkor characterised by ascites and bloated stomach as well as changes in hair colour. An immediate referral was made to the nearest clinic and the child was brought to the district hospital for further nutritional management. Following his discharge from the second round of refeeding, his weight, height and WHZ were 10.1 kg, 86.0 cm, and -2.10, respectively. [This value was calculated using an anthropometric software Anthro version 3.2.2 (WHO, 2011) that provided the exact *z*-score value. Conversely, the hospital used a z-score table as per protocol (HRPB, 2009), where a height of 86.0 cm and weight of 10.0 kg was considered acceptable WHZ].

DISCUSSION

The Malnourished *Orang Asli* Protocols of the Paediatrics Department of *Hospital Raja Permaisuri Bainun* (HRPB, 2009), allows the discharge of a patient from the refeeding programme in district hospital when the patient's WHZ is ≥ -2.00. Upon the patient's discharge, the nearest clinic or mobile team in charge of the child's village should be alerted. One of the primary challenges we found in this case was a lack of effective communication between the hospital and the clinic. From the child's health record book, the weight documented at his follow-up visit in the clinic at one month after his first discharge on 11 September 2017 was 10.3 kg. However, we could not find any discharge note on the child's health book at home nor its copy in the clinic. The data on admission and discharge was only available in his hospital records. Therefore, the clinic could not have known that there was a 700 gram decrease in the child's weight within the one month after discharge (discharge weight was 11.0 kg from the hospital). It was alarming that the child's weight had deteriorated greatly by 13.6%, having decreased from 11.0 kg (at discharge) to 9.5 kg (during visit) within three months after discharge, with a WHZ that fell from -0.87 to below -2.00.

Supplementary feeding was provided to improve the nutritional status of the malnourished child at the clinic. Unfortunately, although the child was previously on the Food Basket Programme, he had defaulted follow-up for six months. According to the child's health record, it was documented that the mother did not collect his food basket from the clinic due to a lack of transport. We confirmed this during an interview with the mother. The mother also found that it was difficult to walk to the clinic with her four children tagging along. From the clinic's health records, it was noted that the health personnel had conducted several home visits prior to the period of default. However, the house was locked with no one available at home as the mother had reportedly gone fishing at the lake. There was also a report of an incident when the mother ran into the jungle to hide from the nurses. Informal conversation with the neighbours revealed that the mother had hypertension, and thus she was afraid of going to the clinic for her child's follow-up fearing that she would be given treatment instead of her child. Following the second discharge from the refeeding programme, the child was again enrolled in the Food Basket Programme. The mother was advised on the importance of nutritious food and the usage of food basket, including the way to dilute the milk properly. She was also given general advice on health, on matters such as the importance of immunisation and attendance for clinic appointments. The child showed slight improvement in his weight gain (1.0 kg within seven months). A recent study found that the Food Basket Programme was five times less likely to succeed among *Orang Asli* children compared to Malay children (Mas-Harithulfadhli-Agus, Hamid & Rohana, 2018). Therefore, inclusion into other supplementary feeding programmes needs to be considered to further improve this child's nutritional status.

Observation of the family house environment and a look at the socio-demographic factors, revealed that the mother of the boy herself was underweight (BMI 17.5 kg/m^2). The vicious cycle of malnutrition was evident in this case, as malnourished mothers are known to give birth to malnourished infants, who then grow into underweight adolescents and adults (Darnton-Hill, Nishida & James, 2004). Indeed, nutritional deficiencies can adversely impact a child's survival and growth starting from the mother's pregnancy until the child reaches 2 years old (UNICEF, 2009; Black *et al.*, 2013). In this case, given that the pregnancy history was unavailable as the mother had not attend any antenatal care at the clinic, and she was not attended to at delivery by a skilled health worker, there is a high likelihood that she would have had a malnourished child (Hamel *et al.*, 2015). Previous studies have reported that higher proportion of mothers with a malnourished child was themselves underweight, and that general health and nutritional status of mothers at birth affect their offspring (Cheah *et al.*, 2012; Wong, Moy & Nair, 2014). Apart from that, malnourishment in this case could also be due to poorly spaced pregnancies. The gap between giving birth to her second child and this boy was only 12 months and the gap between him and his youngest sibling was 21 months. Therefore, this child could have been malnourished from early on in his life. However, this could not be confirmed due to the undocumented pregnancy history.

The causality of under-nutrition is multifactorial. Nutritional status is influenced by primary factors, such as household food insecurity, feeding and care practices, unhealthy household environment and inaccessibility of health services, all of which directly influence nutrient intake and the presence of disease (UNICEF, 1990; UNICEF, 2013). Through a face-to-face interview using food insecurity questionnaire (Zalilah & Ang, 2001), we found that this household experienced child hunger, which is considered the most severe problem arising from household food insufficiency that results in poor diet quality (Zalilah & Tham, 2002). Child hunger, which is characterised by a low quantity of food consumed by children, occurs only after the adult caregivers in the households have been affected by household food shortages. Coming from a background of hardcore poverty, this finding was in line with the mother's claim saying that, *"duit tak cukup, beli sikit-sikit"* (Malay), or *"…money is not enough, so we only buy a little…"* (English translation). This situation directly affected their choices in buying enough food for all household members. However, when there is a shortage in the supply of protein food sources (e.g. when not enough fish caught or when no one can find any protein sources), the *Orang Asli* men eat first, and the women and children go hungry (Bolton, 1972). The nutritionist in-charge also informed us that the *Orang Asli* community do not usually talk about food taboos that they practise as they were worried of being scolded by the healthcare professionals. Understanding the root causes of food unavailability and strengthening it with an ethnographical approach that visualises the real practices in their daily life, will be beneficial in determining their daily food intake practices.

These malnutrition-related factors directly affected the weight gain of the child. From dietary recall that was conducted during the home visit, we found that the child received 852 kcal (Table 1) from his intake on the previous day. This figure did not meet the 980 kcal/day that the Malaysian Recommended Nutrient Intake (RNI) had recommended for his sex and age (NCCFN, 2017). Energy and macronutrient estimation was calculated using the Nutritionist Pro™ Diet Analysis software (Axxya Systems, Woodinville, WA, USA). The percentage of macronutrient contribution to total energy intake was 51.8% carbohydrates, 18.3% protein and 29.9% fat. The main contributor to calories were carbohydrate sources, such as rice and sweetened creamer. The sweetened creamer was low in nutrients, even though it contributed to the child's energy intake due to its high sugar content. The protein intake of the child was more than three times the RNI (12 g/day), for a child aged 1-3 years. It was surprising that protein intake appeared to be so high. However, the dietary recall was done during our home visit in November, which coincided with the rainy season when the lake and river nearby had an abundance of fish, which could explain the high protein intake. The occurrence of malnutrition and relapse in this child, however, had occurred three months earlier, and his weight loss was also not detected during the clinic visit. Hence, case management at the clinic was based on routine follow-up for a child of his age and was not focused specifically on his malnutrition,

Table 1. Dietary findings using 24-hour diet recall taken on the day of visit

Meal	*Food/drinks*	*Quantity*	*Weight (g)*	*Energy (kcal)*	*Carbohydrate (g)*	*Protein (g)*	*Fat (g)*
9.00 am Breakfast	Fried rice[†]	3 dessert spoons	75	145	19.8	3.7	5.7
	Sweetened creamer	2 dessert spoons with 200 ml water	18	61	9.9	1.6	1.6
1.00pm Lunch	White rice	3 dessert spoons	75	125	28.9	2.2	0.1
	Fried *ikan terbul*[‡]	4 small pieces	80	116	0.4	14.3	6.4
	Fried spinach	1 scoop	63	50	1.2	2.3	4.0
	Plain water						
5.00 pm Afternoon snack	Sweetened creamer	2 dessert spoons with 200 ml water	18	61	9.9	1.6	1.6
8.00 pm Dinner	White rice	3 dessert spoons	75	125	28.9	2.2	0.1
	Fried *ikan terbul*	2 small pieces	40	58	0.2	7.2	3.2
	Fried spinach	1 scoop	63	50	1.2	2.3	4.0
	Plain water						
9.00 pm Supper	Sweetened creamer	2 dessert spoons with 200 ml water	18	61	9.9	1.6	1.6
Total				852	110.3	39.0	28.3
% total energy intake (TEI)					51.8	18.3	29.9

[†]Fried rice was prepared using basic ingredients (rice, oil, shallots, anchovies and salt).
[‡]*Ikan terbul* is a type of fish found in rivers and lakes of *Tasik Banding*, Perak, with weight ranging from 20g (small fish) to 80g per piece.

which explained the lack of dietary data from that time period.

There are some limitations in this case report. As recorded in the child's health book, advice was given to the mother, but we were unable to assess the knowledge of the mother and her perception towards malnutrition among her children. This case report highlighted the importance of a mother's knowledge in providing and preparing nutritious food for her child as well as the barriers she faced in attending clinic to seek treatment for herself (hypertension) and her child (malnutrition). The involvement and motivation of both parents are crucial in avoiding a recurrence of malnutrition in the future. There was also a need for good communication between the hospital and the clinic in monitoring a malnourished child's progress. Although the management of this case was done based on the guidelines and the existing standard operating procedure (SOP) for malnourished children, the information shared following the child's discharge from hospital should have been delivered to the clinic or mobile team in-charge of the patients.

CONCLUSION

In conclusion, the child was still malnourished despite having been successfully treated in the hospital when he was first admitted. The successful nutrition management of a severely malnourished child requires both medical and social needs to be satisfied by all stakeholders. Therefore, identification of the possible causes of the malnutrition, such as economic status, food security, knowledge, attitude and practices that may affect nutritional status, as well as motivators and barriers towards the treatment and follow-up faced by the family, would be beneficial in planning specific interventions for *Orang Asli* children.

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Authors' contributions

AAR conceptualised and designed the study, undertook data collection, data analysis, interpretation, and preparation of the draft of the manuscript; TSF advised on the data analysis and interpretation, assisted in the drafting and review of the manuscript; IMS assisted in drafting the manuscript; MSIMS and NMN, conducted data collection in the Hulu Perak district; SMJ, assisted in the drafting and review of the manuscript; PBK, the principal investigator, conceptualised, designed and conducted the study, led the data collection and reviewed the manuscript.

Conflict of interest

The authors declare no conflict of interest arising from the findings for the reported case and its management.

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Validation of the 28-day mortality prognostic performance of the modified Nutrition Risk in Critically Ill (mNUTRIC) score in a Malaysian intensive care unit

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ABSTRACT

Introduction: The mNUTRIC score is a nutritional assessment tool to identify critically ill patients with high nutritional risk who could benefit from nutritional interventions. This study was conducted to validate the 28-day mortality prognostic performance of the mNUTRIC score in a Malaysian intensive care unit (ICU). **Methods:** This was a retrospective cohort study of adult patients who were consecutively admitted to the ICU from January 2017 to December 2018 for >24 hours. Data were collected on variables required to calculate the mNUTRIC score. Patients with mNUTRIC score ≥5 points were considered to be at high nutritional risk. Main outcome was 28-day mortality from all causes; ICU length of stay (LOS) and prolonged mechanical ventilation (MV) (>2 days) were secondary outcomes. **Results:** From a total of 432 admissions, 382 (88.4%) patients fulfilled the study criteria. Seventy-seven (20.2%) of these patients were at high nutritional risk. They had longer mean ICU LOS (7.1±7.5 days versus 4.2±4.0 days, p=0.001), greater proportion of prolonged MV (57.1% versus 14.4%, p<0.001) and higher 28-day mortality (44.2% versus 10.2%, p<0.001) compared to patients with low mNUTRIC score (≤4 points). High mNUTRIC score predicted 28-day mortality with area under the curve (AUC) of 0.797 (95% confidence interval: 0.738-0.856). **Conclusion:** High mNUTRIC score was associated with a higher 28-day mortality. The prognostic performance for 28-day mortality of the mNUTRIC score is clinically valid as indicated by AUC >0.7 and is comparable to the results of other validation studies. In addition, patients with high mNUTRIC score had increased ICU LOS and prolonged MV.

Keywords: Nutritional status, critically ill, mortality

INTRODUCTION

It is the standard practice to provide nutritional support to critically ill patients in order to treat existing malnutrition and minimise adverse clinical outcomes. Adequate nutritional support for these patients has been shown to improve clinical outcomes, particularly in patients at 'high nutritional risk' (Kondrup *et al.*, 2003). Therefore, identifying critically ill patients who are at high risk of malnutrition is an important role of

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intensivists. Nonetheless, evaluating nutritional risk of critically ill patients remains a challenge for intensivists for a variety of reasons. First, critically ill patients are often intubated which poses a communication barrier to obtaining an accurate dietary history. Second, anthropometric measures may be obscured by oedema while voluntary handgrip strength is impractical in unconscious patients. Third, laboratory measures, such as pre-albumin and albumin levels, lymphocyte counts and transferrin, are abnormal in critical illness (Bersten & Soni, 2014).

In 2011, Heyland *et al.* introduced the Nutrition Risk in Critically Ill (NUTRIC) score, the first nutritional risk assessment tool that was developed for intensive care unit (ICU) patients (Heyland *et al.*, 2011). The score identifies high nutritional risk patients who will benefit from aggressive nutritional support by linking starvation, inflammation and outcomes (Heyland *et al.*, 2011). It consists of six variables, which are age, the Acute Physiology and Chronic Health Evaluation (APACHE) II score, the Sequential Organ Failure Assessment (SOFA) score, the number of co-morbidities, the number of days from hospital to ICU admission, and blood interleukin-6 (IL-6) concentration. Patients get 1-3 points for each variable and the highest score adds up to 10 points. Those who score ≥5 points are considered to be at high risk for malnutrition.

However, the IL-6 levels are not commonly measured in many institutions. Heyland *et al.* (2011) have stated that IL-6 only increased the area under the curve (AUC) by 0.007 (from 0.776 to 0.783), being neither clinically nor statistically different. They have therefore suggested that in settings where IL-6 is not available this parameter could be dropped from the calculation of the score. This adjusted score is called the modified NUTRIC (mNUTRIC) score (Table 1). Because the IL-6 component is dropped, the mNUTRIC score adds up to 9 points. Rahman *et al.* (2016) have demonstrated the validity of the mNUTRIC Score in an external population and this was followed by several other validation studies (De Vries *et al.*, 2018; Jeong *et al.*, 2018; Jung *et al.*, 2018; Mendes *et al.*, 2017; Moretti *et al.*, 2014). Nonetheless, these studies were mainly conducted in the setting of western ICUs or in high-income countries. The evidence for validation of the mNUTRIC score in the low- and middle-income countries are very limited (Kalaiselvan, Renuka & Arunkumar, 2017). Thus, the purpose of the present study was to validate the prognostic performance of the mNUTRIC score in a Malaysian ICU, as reflected by the impact on 28-day mortality, length of stay (LOS) in the ICU and duration of mechanical ventilation (MV).

MATERIALS AND METHODS

This was a retrospective cohort study that was conducted in the ICU of International Islamic University (IIUM) Medical Centre in Pahang, Malaysia from 12 January 2017 to 31 December 2018. The study was approved by the IIUM research and ethics committee (IREC). Written informed consent of the patients could not be obtained because of the retrospective nature of the study design. Consecutive adult patients (aged ≥18 years) admitted to the ICU for >24 hours were included in the study. Those who were readmitted and with ICU LOS of <24 hours were excluded from the analysis. We reviewed the ICU charts and the electronic medical records to collect data on baseline demographic and clinical characteristics, the parameters required to calculate the mNUTRIC score and outcome data. The main outcome was 28-day mortality from all causes;

Table 1. The parameters required for the calculation of the mNUTRIC score

Variable†	*Range*	*Points*
Age (years)	<50	0
	50 to <75	1
	≥75	2
APACHE II	<15	0
	15 to <20	1
	20 to 28	2
	≥28	3
SOFA	<6	0
	6 to <10	1
	≥10	2
Number of co-morbidities	0 to 1	0
	≥2	1
Days from hospital to ICU admission	0 to <1	0
	≥1	1

Sum of points	*Category*	*Explanation*
5-9	High score	Associated with worse clinical outcomes (mortality, ventilation)
0-4	Low score	The patients have a low malnutrition risk

†APACHE, Acute Physiology and Chronic Health Evaluation; ICU, intensive care unit; SOFA, Sequential Organ Failure Assessment

ICU LOS and prolonged MV (>2 days) were secondary outcomes.

All statistical analyses were performed using SPSS version 24.0 (IBM, Armonk, New York, USA) and MedCalc for Windows, version 17.5.5 (MedCalc Software, Ostend, Belgium). Continuous variables were presented as mean±standard deviation (SD) while categorical variables were presented as frequencies (percentages). Patients with a mNUTRIC score ≥5 points were considered to be at high nutritional risk while those with score ≤4 points were considered low nutritional risk. Univariate comparison of the continuous variables between these two groups was analysed using the independent t-test. Univariate comparison of the categorical variables between these two groups was analysed using the chi-squared test. $P<0.05$ was considered statistically significant for all tests. The prognostic performance of the mNUTRIC score was assessed by the AUC of the receiver operating characteristic (ROC) curve of sensitivity against (100-specificity) across a series of the score's readings. The AUC ranges from 0.5 (no discrimination) to 1.0 (perfect discrimination). Clinical validity was assumed to be at an AUC of >0.7 (Bewick, Cheek & Ball, 2004). The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR) and negative likelihood ratio (NLR) of the score were determined from the ROC curve analysis. The AUC, sensitivity, specificity, predictive values and likelihood ratios were reported with 95% confidence interval (CI).

RESULTS

Baseline demographic and clinical characteristics

A total of 432 patients were admitted to the ICU during the study period. Fifty (11.6%) patients were excluded from the study; 19 (4.4%) patients were underaged, 23 (5.3%) patients were readmission cases and 8 (1.9%) patients had an ICU LOS of <24 hours (Figure 1). Thus, the data of 382 (88.4%) patients were analysed. A total of 77 of the 382 (20.2%) patients were at high nutritional risk (mNUTRIC score ≥5 points). The baseline demographic and clinical characteristics of the patients who were included in the analyses are shown in Table 2. The patients who were at high nutritional risk were older (66±9 years versus 54±16 years, $p<0.001$) and the majority of them were medical cases (66.2% versus 44.9%, $p=0.001$). Sepsis (26.0% versus 14.8%, $p=0.019$) and shock (26.0% versus 11.5%, $p=0.001$) were more commonly noted as the reasons for ICU admission among the high nutritional risk patients compared to the patients with low nutritional risk. The mean mNUTRIC score in the overall population was 2.9±1.9 points. As expected, the mean score was higher in the high nutritional risk than in the low nutritional risk group (5.8±0.9 points versus 2.2±1.4 points, $p<0.001$).

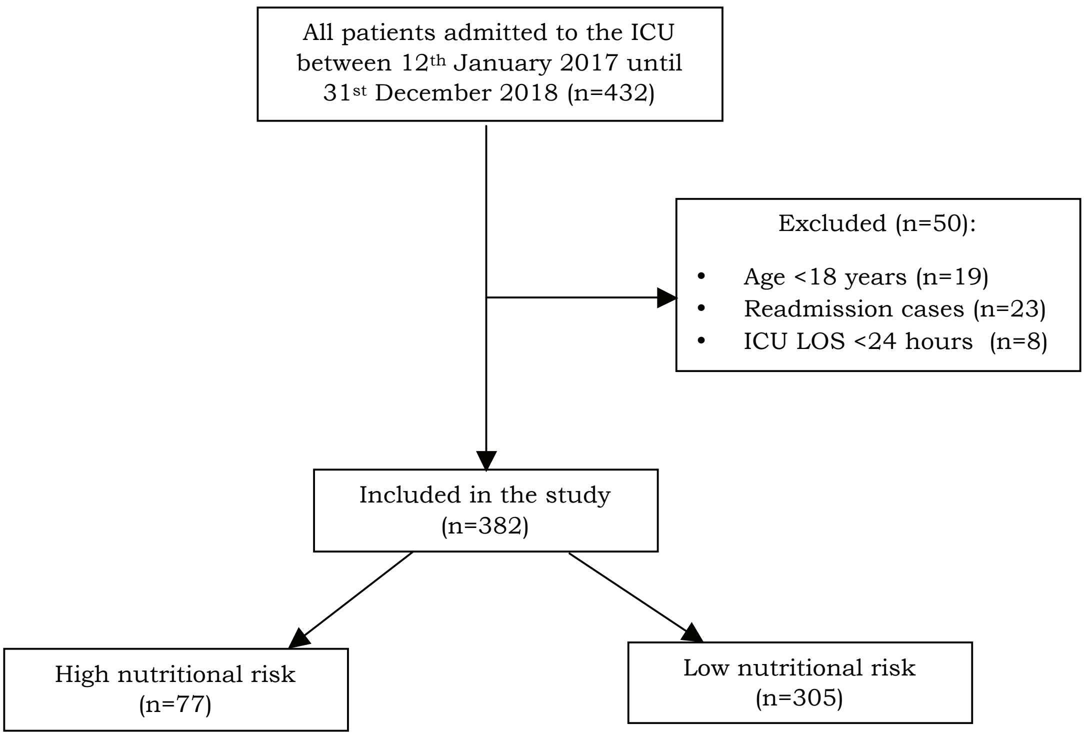

Figure 1. Flowchart of patients' selection
Note: ICU, Intensive care unit; LOS, length of stay

Table 2. Baseline demographics and clinical characteristics

Variables[†]	*All patients (N=382)*	*Low nutritional risk (n=305)*	*High nutritional risk (n=77)*	*p*
Demographics				
Age (years), mean±*SD*	57±16	54±16	66±9	<0.001
Sex				
Male, n (%)	216 (56.5)	168 (55.1)	48 (62.3)	0.251
Female, n (%)	166 (43.5)	137 (44.9)	29 (37.7)	
BMI (kg/m^2), mean±*SD*	26.3±7.5	26.0±5.4	27.6±14.1	0.811
Clinical				
Admission category, n (%)				
Medical	188 (49.2)	137 (44.9)	51 (66.2)	0.001
Surgical	194 (50.8)	168 (55.1)	26 (33.8)	0.001
Reasons for ICU admission, n(%)				
Post-operative care	127 (33.2)	120 (39.3)	7 (9.1)	<0.001
Respiratory failure	107 (28)	83 (27.2)	24 (31.2)	0.490
Sepsis	65 (17)	45 (14.8)	20 (26.0)	0.019
Shock	55 (14.4)	35 (11.5)	20 (26.0)	0.001
Neurological deterioration	27 (7)	21 (6.9)	6 (7.8)	0.781
Toxicity	1 (0.4)	1 (0.3)	0 (0)	0.615
Severity of illness, mean±*SD*				
APACHE II	13.0±7.7	10.8±6.1	23.1±5.7	<0.001
SOFA	4.0±3.8	2.9±2.9	8.4±3.6	<0.001
mNUTRIC score	2.9±1.9	2.2±1.4	5.8±0.9	<0.001

[†]APACHE, Acute Physiologic Assessment and Chronic Health Evaluation; BMI, body mass index; ICU, Intensive care unit; mNUTRIC, modified Nutritional Risk in Critically Ill; SOFA, Sequential Organ Failure Assessment

Prognostic performance of the mNUTRIC score

The outcomes of the overall population and as stratified by the nutritional risk are presented in Table 3. The primary outcome of 28-day mortality was reached in 65 (17.0%) patients. Patients who were at high nutritional risk had higher 28-day mortality compared to patients at low (mNUTRIC score ≤4 points) nutritional risk (44.2% versus 10.2%, *p*<0.001). The mNUTRIC score on a full scale (0-9) predicted mortality with AUC of 0.797 (95% CI, 0.738-0.856), indicating a very good prognostic performance of the score in our cohort (Figure 2).

At the optimal cut-off of 6 points, the mNUTRIC score showed the following characteristics:

Sensitivity: 18.5% (95% CI, 9.9-30.0%)
Specificity : 98.4% (95% CI, 96.4-99.5%),
PPV : 70.6% (95% CI, 46.7-86.8%),
NPV : 85.5% (95% CI, 84.0-86.9%),
PLR : 11.7 (95% CI, 4.3-32.1%)
NLR : 0.8 (95% CI, 0.7-0.9%)

In addition, patients who were at high nutritional risk also had longer mean ICU LOS (7.1±7.5 days versus 4.2±4.0 days, *p*=0.001) and greater proportion of prolonged MV (57.1% versus 14.4%, *p*<0.001).

Table 3. Comparison of outcomes of patients with high nutritional risk (mNUTRIC score ≥5 points) and low nutritional risk (mNUTRIC score ≤4 points)

Variables†	*All patients (N=382)*	*Low nutritional risk (n=305)*	*High nutritional risk (n=77)*	*p*‡
ICU LOS (days), mean±*SD*	4.8±5.1	4.2±4.0	7.2±7.5	0.001
Prolonged mechanical ventilation (>2 days), n (%)	88 (23)	44 (14.4)	44 (57.1)	<0.001
28-day mortality, n (%)	65 (17)	31 (10.2)	34 (44.2)	<0.001

†ICU, intensive care unit; LOS, length of stay
‡The results of the comparison between the two groups was analysed by the independent t-test for continuous variable or the chi-squared test for categorical variables

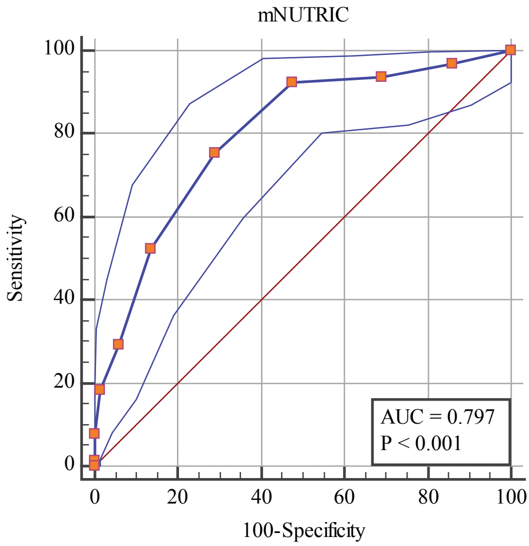

Figure 2. Prognostic performance of the mNUTRIC score on a scale of 0-9 in predicting 28-day mortality in critically ill patients

Note: mNUTRIC, modified Nutrition Risk in Critically Ill; AUC, area under the curve

DISCUSSION

As identification of critically ill patients with high nutritional risk is important to reduce poor clinical outcomes, the need for an easy-to-implement, low cost, highly-effective scoring system is undeniable. Many of the traditionally used nutritional screening tools such as the Malnutrition Universal Screening Tool, the Nutritional Risk Screening (NRS 2002) and the Subjective Global Assessment use anthropometric measurements and the history of dietary intake or weight loss to identify patients at nutritional risk (Detsky *et al.*, 1987; Elia, 2003; Kondrup *et al.*, 2003). Anthropometric measures can be unreliable in ICU patients because of underlying oedema and a reliable history of dietary intake or weight loss is difficult to obtain as these patients are often intubated and sedated. The NUTRIC score was the first nutritional risk assessment tool that had been developed specifically for ICU patients. Although the NUTRIC score is effective, the inclusion of the costly and often unavailable IL-6 measurement makes it unattractive for widespread implementation. As such, the mNUTRIC score appears to be the more promising nutritional risk assessment tool but further validation is warranted.

The main objective of this study was to validate the prognostic performance of the mNUTRIC score mainly for mortality, in our local ICU setting. In this study, we found that 20.2% of patients admitted to our ICU were at high nutritional risk (mNUTRIC score ≥5 points). This percentage was lower than that reported by Mendes *et al.* (2017) (48.6%) and Kalaiselvan *et al.* (2017) (42.5%) who also employed the mNUTRIC score in assessing the prevalence of malnutrition in ICU patients. In our cohort, the mNUTRIC score had a good performance in predicting mortality, as indicated by an AUC of 0.797. This is comparable to two other recent validation studies where the AUC of the mNUTRIC score for 28-day mortality was 0.768 in a Dutch ICU (De Vries *et al.*, 2018) and 0.757 in a Korean ICU (Jeong *et al.*, 2018). This finding suggests that the mNUTRIC score is a good prognostic substitute for the NUTRIC in assessing nutritional risk in the ICU. As with the Korean study by Jeong *et al.* (2018), we found that the cut-off of 6 points for the mNUTRIC score was better at predicting 28-day mortality than the cut-off of 5 points as suggested by the original NUTRIC score. Our study found that the mNUTRIC score was also valid in predicting other clinical outcomes such as longer ICU LOS and prolonged MV, in line with the previous findings by others (De Vries *et al.*, 2018; Kalaiselvan *et al.*, 2017; Mendes *et al.*, 2017).

This study has several strengths. To our knowledge, our study is the first to validate the prognostic utility of the mNUTRIC score in the local ICU setting. Nutritional risk assessment is an important part of the management of critically ill patients but is often overlooked. Unlike the original NUTRIC score, with the exception of IL-6 level, the mNUTRIC score is easier to calculate. Given our results, we recommend the introduction of the mNUTRIC score for the nutritional risk assessment of our critically ill patients considering its suitability and feasibility. The mNUTRIC score may also have utility in the design and interpretation of clinical trials of nutrition in the ICU setting. Second, our study strengthens the evidence obtained by a previous study (Jeong *et al.*, 2018) that the optimal cut-off of the mNUTRIC score for mortality was 6 points, in contrast to the cut-off of 5 points as suggested by the original NUTRIC score. Third, our study was conducted in a cohort of mixed medical and surgical ICU patients; this may allow the general application of the results obtained to all critically ill patients.

Nevertheless, our study has several limitations. First, we did not calculate the nutritional support provided to the patients. Therefore, the association between nutritional adequacy, mNUTRIC score and mortality could not be confirmed by our results. However, this was not the main aim of the study. This study was conducted primarily with the aim of validating the prognostic performance of the mNUTRIC score in our local ICU setting. The second limitation of our study was our inability to obtain IL-6 levels of the patients. Even though our intent was to examine the score without IL-6, a comparison with IL-6 would have allowed us to see the difference between the NUTRIC and mNUTRIC scores. Third, it may also be a limitation to the current validation of the mNUTRIC score that it is based on 28-day mortality, which was the only mortality data available for use in this dataset. Choosing longer term outcomes, such as 90-day mortality or some measure of functional status at hospital discharge may have yielded different but important results**.** Fourth is the limitation related to that of the NUTRIC score itself; clinicians may argue that there is little need for another risk score since those such as APACHE II or SOFA score are available. The calculation of the score can be cumbersome, thus limiting its clinical utility. Others correctly point out that the NUTRIC score does not contain traditional nutrition variables. Unfortunately, in an ICU setting, these variables depend on history from family members, which can be inconsistent.

Finally, our study was conducted at a single centre, and its findings cannot be generalised to the wider external population.

CONCLUSION

The ability of the mNUTRIC score to discriminate between high and low risk for 28-day mortality in Malaysian ICU patients is clinically valid and comparable with that found in previous validation studies. Our results also confirmed the association of high mNUTRIC scores with prolonged MV and longer ICU stay. We therefore suggest the introduction of the mNUTRIC score for the nutritional risk assessment of critically ill patients in Malaysian ICUs. However, further multicentre prospective studies are warranted to show the effect of nutritional interventions in critically ill patients.

Acknowledgement

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Authors' contributions

WFWMS conducted the study, data analysis and interpretation, assisted in drafting of the manuscript, reviewed the manuscript; SS undertook data collection and reviewed the manuscript; AMR advised on the data analysis and interpretation and reviewed the manuscript; MBMN, the principal investigator, conceptualised and designed the study, prepared the draft manuscript and reviewed the final manuscript.

Conflict of interest

The authors declare no conflict of interest.

List of abbreviations used in the text

APACHE, Acute Physiology and Chronic Health Evaluation; ICU, intensive care unit; IL-6, interleukin-6; LOS, length of stay; mNUTRIC, modified Nutrition Risk in Critically Ill; NUTRIC, Nutrition Risk in Critically Ill; MV, mechanical ventilation; SOFA, Sequential Organ Failure Assessment

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A retrospective study of weight-loss predictors following bariatric surgery in Malaysian patients with obesity

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ABSTRACT

Introduction: A retrospective study was conducted with the aim of determining the factors that affect weight loss among post-bariatric surgery patients. **Methods:** A successful weight loss outcome in this study was defined as achieving at least 50% excess weight loss (EWL). Eligible participants were those who had undergone bariatric surgery at least two years prior to the study. Adherence to lifestyle recommendations post-bariatric surgery, binge eating, depression, and social support were assessed. **Results:** A total of 51 post-bariatric surgery patients were recruited with a mean post-operative period of 3.2±0.7 years. The mean pre-operative weight of 116.6±28.8 kg and body mass index (BMI) 45.2±8.8 kg/m^2 were significantly reduced to 86.6±21.0 kg and 33.6±6.7 kg/m^2, respectively, during follow-up (p<0.001). A total of 66.7% of participants achieved successful weight loss following bariatric surgery, with a mean EWL of 73.6±21.9% and total weight loss (TWL) of 29.4±8.7%. According to multivariate regression analysis adjusted for age and gender, pre-operative weight (β=-1.580, p<0.05) and BMI (β=-1.398, p<0.05), rate of weight loss (β=1.045, p<0.01), and adherence to eating behaviour recommendations (β=0.177, p<0.05) were significant predictors of weight loss outcomes post-bariatric surgery. **Conclusion:** The lower pre-operative weight and BMI, the faster rate of weight loss and higher adherence towards eating behaviour advice were potential predictors of greater EWL and thus could increase the chance of successful weight loss maintenance post–bariatric surgery.

Keywords: Obesity, bariatric surgery, pre-operative weight, dietary adherence, rate of weight loss

INTRODUCTION

Obesity and increases in fat accumulation, including visceral adiposity, especially in the upper body, is linked to the risk of developing type II diabetes mellitus (T2DM), cardiovascular disease, and metabolic syndrome (Eckel *et al.*, 2011). Bariatric surgery is

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considered to be one of the recommended treatments for morbid obesity because it effectively promotes durable weight loss in most patients with obesity for the first 18 months post-surgery (Concors *et al.*, 2016). Nevertheless, regaining lost weight after 2 to 10 years post-bariatric surgery is common (McGrice & Don Paul, 2015).

Bariatric surgery only accounts for half of requirements for patient with morbid obesity to lose weight. The other half comes from behavioural modification, dietary recommendations, and exercise with psychological support to maximise the surgery's benefits (Liu, 2016). Participants who adhered to the dietary recommendations and grazed no more than once a day showed the highest weight loss (Robinson *et al.*, 2014). Further reduction in body weight post-bariatric surgery requires support from peer, dietetic, and psychological groups (Sharman *et al.*, 2017).

A recent study found that pre-operative weight significantly predicted weight loss (Vanoh, Shahar & Nik Kosai, 2015). However, psychosocial variables were not associated with the rate of weight loss in that study and other studies of one-year post-bariatric surgery patients (Fox *et al.*, 2015). Adherence to dietary recommendations was not associated with weight loss during a short-term assessment of successful post-bariatric surgeries (Sherf-Dagan *et al.*, 2017). There is thus a need to investigate the medium-term success of weight loss post-bariatric surgery, with special emphasis on dietary adherence and psychosocial variables. Thus, the present study aimed to determine the pre-operative, dietary, lifestyle, and psychosocial factors that affect weight loss in the medium-term follow-up.

MATERIALS AND METHODS

Study design and sampling

This was a retrospective study of post-bariatric surgery patients from the Obesity Clinic, University Kebangsaan Malaysia Medical Centre (UKMMC). Data collection was undertaken from September until December 2016. The list of patients who underwent bariatric surgery from January 2012 to December 2014 was obtained from the Surgical Department of UKMMC. Participants were recruited via convenience sampling. The inclusion criteria were patients ≥18 years of age and they had to be at least 2 years after bariatric surgery had been performed. The exclusion criteria were pregnancy, severe mental illness, mental disabilities, deafness, and patients undergoing revision surgery during the period of study. Initially, patients were invited to participate in this study by the researchers through phone calls. A self-reported questionnaire was sent to patients who agreed to participate via post and email. Depending on the preference of the participants, reminders were sent through phone messages and email, requesting that they complete their questionnaire. Meanwhile, patients who attended the Obesity Outpatient Clinic of UKMMC for follow-up were directly invited to participate in this research. Out of 123 patients who were identified as prospective participants, 68 responded to the invitation and agreed to participate. However, only 51 patients were recruited as participants because some were excluded due to incomplete questionnaires (n=3), failure to return the questionnaires (n=10) or because they withdrew (n=4) from the study. Informed consent was obtained from all participants. This study received ethical approval (NN-2016-048) from the Research and Ethical Committee of Medical Research of Universiti Kebangsaan Malaysia.

Outcome measures

Self-reported weight were used for the participants who were recruited through phone calls, while the height measurement were obtained from medical records. There was a significant correlation between measured and reported weight and height (Ivezaj & Grilo, 2017). Whereas, the height and weight were measured for participants who were recruited at the Obesity Clinic. The current weight was used to calculate the post-operative body mass index (BMI) as well as the excess weight loss (EWL) and total weight loss (TWL) percentages (Ivezaj & Grilo, 2017). The EWL percentage was calculated using the formula described by Deitel, Gawdat & Melissas (2007): EWL % = 100 x (pre-operative weight – current body weight)/(pre-operative weight – ideal body weight at BMI 25 kg/m2) (Greenstein & Deitel, 2007). The TWL percentage was calculated as: TWL % = 100 x (pre-operative weight – current body weight)/(pre-operative weight) (Pekkarinen *et al.*, 2016). Height, pre-operative weight, type of bariatric surgery, date of bariatric surgery, the number of follow-up visits at the Obesity Clinic, and weight history upon each follow-up (at 3, 6, 9 months, and 1 and 2-year post-surgery) were obtained from medical records. Successful weight loss maintenance among post-bariatric patients was defined as ≥50% EWL (Fox *et al.*, 2015).

Materials

The Bariatric Surgery Self-Management Questionnaire (BSSQ) was used to measure perceived adherence of participants to the lifestyle recommendations for post-bariatric surgery (Welch *et al.*, 2008). The questionnaire was translated into *Bahasa Malaysia* (Malay language) using back-to-back translation with a Cronbach's alpha of 0.85. This questionnaire was in the Likert scale format with choices of "never", "sometimes", "mostly", and "always". The total score was converted into a 0 to 100 range. A higher score indicated a higher adherence of participants to the recommendations.

The Binge Eating Scale (BES) was used to assess binge eating behaviour in participants (Gormally *et al.*, 1982). The validated *Bahasa Malaysia* version of the BES, with a Cronbach's alpha of 0.89, was used in this study (Robert *et al.*, 2013). In addition, the Beck Depression Inventory (BDI) was used to measure the presence and degree of depression (Beck, Steer & Brown, 1996). The *Bahasa Malaysia* version was adopted from Vanoh *et al.* (2015) with a Cronbach's alpha of 0.93.

The Duke Social Support and Stress Scale (DUSOCS) (Parkerson, Broadhead & Tse, 1991) was used to measure the support and stress from the social environment of the participants. In this study, only the social support part of the questionnaire was utilised. The questionnaire consisted of two domains: social support from family members (including both blood related and non-blood related) and non-family members, such as neighbours, colleagues, and friends. The *Bahasa Malaysia* translation of DUSOCS from Hudin *et al.* (2017) was adopted with Cronbach's alpha of 0.53 for the family domain and 0.70 for the non-family domain.

Statistical analysis

The categorical data are presented as the frequency and percentage, while for continuous data, the mean and standard deviation (SD) are reported. Survival analysis (time-to-event) was used because each recruited participant had a different post-operative period and this study also included participants who did not achieve a successful weight loss outcome post-operatively (censored data). The log rank test was used to compare survival between different groups. Univariate and multivariate regressions were employed to determine the factors that affected weight loss post-bariatric surgery. Statistical analysis was performed using SPSS version 22 (IBM Corp., Armonk, NY). The statistical significant was set at $p<0.05$.

RESULTS

As shown in Table 1, the age of the participants ranged from 20 to 60 years old, with a mean of 45.5±8.9 years. The majority of participants were women (68.6%), Malays (84.3%), and married (72.5%). The mean post-operative period was 3.2±0.7 years, ranging from 2.1 to 4.8 years (25.3 to 58.7 months). A total of 41 participants underwent sleeve gastrectomy-bariatric surgery (80.4%), nine participants received Roux-en-Y gastric bypass (RYGB) (17.6%) and one participant underwent laparoscopic adjustable gastric banding (LAGB) (2.0%).

Participants (n=34, 66.7%) who successfully maintained their weight loss (≥50% EWL) lost significantly higher percent EWL (73.6±21.9% vs 35.7±9.4%, $p<0.001$) and TWL (29.4±8.7% vs 16.1±4.7%, $p<0.001$) compared with participants (n=17, 33.3%) who experienced sub-optimal weight loss (<50% EWL) (data not shown). Table 2 shows that there were no significant differences observed in post-operative weight and BMI and the EWL and TWL percentages when participants were grouped into their respective post-operative years (from year 2 to year 4). Nonetheless, the mean rate of weight loss was the highest in participants at 2 years post-bariatric surgery (1.2±0.7 kg/month) compared with those at 3 years (0.7±0.3 kg/month) and 4 years (0.5±0.2 kg/month) ($p<0.05$) post-bariatric surgery. Figure 1 shows the difference in rate of weight loss between the successful weight loss maintainers and the sub-optimal weight loss group. There were no significant differences observed during the first 3 months post–bariatric surgery between the group. However, a significant difference was observed from 6 months onwards. Kaplan-Meier analysis was used to quantify the time-frame over which participants achieved at least a 50% EWL. According to the

Table 1. Demographic data of participants

Variable	*Total (N=51)*	*Men (n=16)*	*Women (n=35)*	*p-value*
Age† (years), mean±*SD*	45.5±8.9 (range: 20–60)	44.5±10.5	45.6±8.2	0.686
Gender‡, *n* (%)				
Men	16 (31.4)			
Women	35 (68.6)			
Ethnicity‡, *n* (%)				0.240
Malay	43 (84.3)	12 (75.0)	31 (88.6)	
Chinese	1 (2.0)	1 (6.25)	-	
Indian	5 (9.8)	2 (12.5)	3 (8.6)	
Others	2 (3.9)	1 (6.25)	1 (2.8)	
Marital status‡, *n* (%)				0.322
Single	9 (17.6)	4 (25)	5 (14.3)	
Married	37 (72.5)	10 (62.5)	27 (77.2)	
Divorcee/widow/widower	5 (9.8)	2 (12.5)	3 (8.5)	
Post-operative period† (years), mean±*SD*	3.2±0.7 (range: 2.1–4.8)	3.4±0.6	3.2±0.7	0.416
Type of surgery, *n* (%)				
Sleeve gastrectomy	41 (80.4)	12 (75.0)	29 (82.9)	
Roux-en Y gastric bypass	9 (17.6)	4 (25.0)	5 (14.3)	
Adjustable gastric banding	1 (2.0)	0	1 (100)	

†using independent t-test; ‡using Chi-square test

Table 2. Anthropometric data at various time intervals following surgery

Variables	*2 years (n=18)*	*3 years (n=22)*	*4 years (n=11)*
Pre-operative weight (kg), mean±*SD*	121.6±32.9	116.4±28.4	108.7±22.9
Post-operative weight (kg), mean±*SD*	83.3±19.4	89.9±21.9	85.2±22.6
Pre-operative BMI (kg/m^2), mean±*SD*	46.6±11.5	45.2±7.5	42.7±6.0
Post-operative BMI (kg/m^2), mean±*SD*	31.9±6.6	35.1±6.9	33.4±6.4
% EWL, mean±*SD*	72.2±26.6	53.6±24.8	57.3±22.2
% TWL, mean±*SD*	29.9±11.5	22.3±8.1	22.1±7.0
Rate of weight loss (kg/month), mean±*SD*	1.2±0.7*	0.7±0.3*	0.5±0.2**
Proportion with ≥50% EWL, *n* (%)	14 (77.8)	11 (50.0)	8 (72.7)

*p-value<0.05; **p value<0.001 statistically significant using ANOVA test

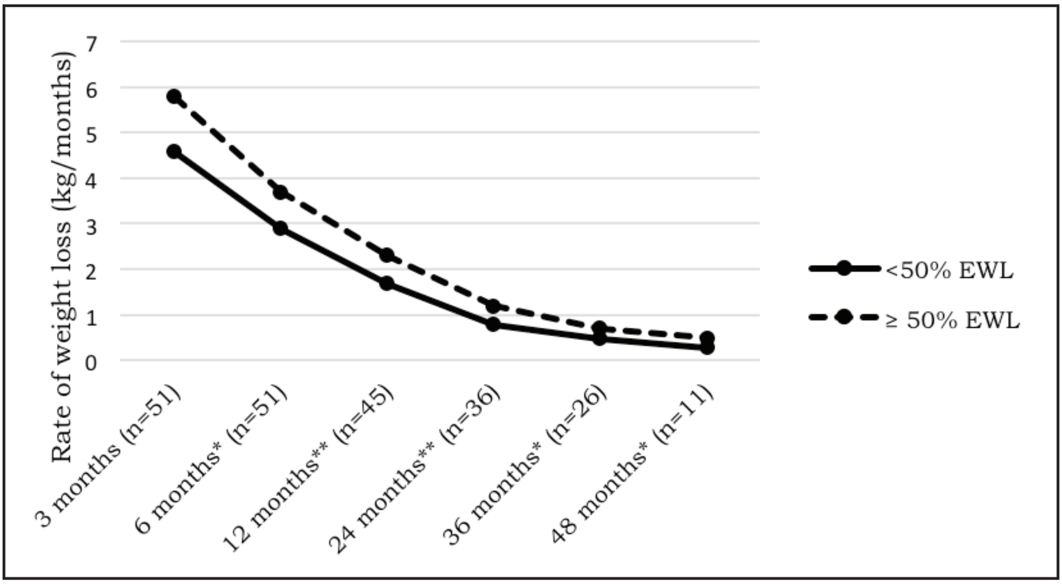

Figure 1. Rate of weight loss between ≥50% EWL and <50% EWL
*p-value<0.05, **p value<0.01 significant in independent t-test

result of the Kaplan-Meier analysis, the overall median of time for participants in this study to achieve a 50% EWL was 12 months (95% CI: 7.8 to 16.2 months).

Participants who successfully maintained their weight loss perceived better adherence to eating behaviour and water intake recommendations and engaged in more physical activity. However, participants who did not achieve a 50% EWL in this mid-term follow-up perceived better adherence towards protein, fruits, vegetables, and vitamin intake recommendations, received more support, and had a lower level of depression and binge eating score compared with the successful group (Table 3). There were no significant differences observed in regard to the BSSQ score, binge eating episodes, depression, and support obtained between participants who achieved a 50% EWL and those who did not. All of the predictors for mid-term weight loss post-bariatric surgery were tested via univariate regression analysis

Table 3. BSSQ components and psychosocial profile of participants

Variables	*Total (N=51)*	*<50% EWL (n=18)*	*≥50% EWL (n=33)*	*p-value*	*95% CI*
Bariatric Surgery Self-Management Questionnaire (BSSQ)†, %±*SD*	56.2±15.3	56.9± 17.1	55.9±14.4	0.836	–8.1, 10.0
BSSQ – Eating Behaviour†	67.9±20.1	64.8±18.2	69.7±21.1	0.413	–16.8, 7.0
BSSQ – Protein†	63.1±21.0	64.4±21.1	62.4±21.3	0.752	–10.5, 14.5
BSSQ – Water Intake†	50.7±21.3	50.3±21.7	50.8±21.4	0.933	–13.2, 12.1
BSSQ – Fruit, Veggie, Whole grain†	52.7±20.8	58.6±25.7	49.5±17.1	0.189	–4.8, 23.1
BBSQ – Physical Activity†	44.4±23.7	42.6±29.3	45.5±20.5	0.685	–16.9, 11.2
BSSQ – Vitamin Intake†	49.7±34.2	57.4±31.9	45.5±35.2	0.237	–8.1, 32.0
Binge Eating Scale†, mean±*SD*	8.4±6.9	7.7±4.6	8.8±7.9	0.586	–5.2, 3.0
BECK Depression Inventory†, mean±*SD*	9.5±11.5	8.8±11.4	9.8±11.7	0.780	–7.8, 5.9
DUSOCS Social Support†, mean±*SD*	39.9±24.7	45.5±27.3	36.9±23.1	0.243	–6.0, 23.0
DUSOCS Family Support‡, mean±*SD*	40.9±27.3	47.2±27.5	37.4±27.0	0.225	–6.2, 25.8
No support, *n* (%)	5 (9.8)	2 (11.1)	3 (9.1)		
Low support, *n* (%)	27 (52.9)	8 (44.4)	19 (57.6)		
Moderate support, *n* (%)	9 (17.6)	4 (22.2)	5 (15.2)		
High support, *n* (%)	10 (19.6)	4 (22.2)	6 (18.2)		
DUSOCS Non-Family Support‡, mean±*SD*	30.6±22.9	33.9±28.9	28.8±19.1	0.508	–10.5, 20.7
No support, *n* (%)	6 (11.8)	2 (11.1)	4 (12.1)		
Low support, *n* (%)	24 (47.1)	8 (44.4)	16 (48.5)		
Moderate support, *n* (%)	10 (19.6)	3 (16.7)	7 (21.2)		
High support, *n* (%)	11 (21.6)	5 (27.8)	6 (18.2)		

†using independent t-test; ‡using Chi-square test

(Table 4) prior to multivariate analysis. Only the pre-operative BMI, percentage of pre-operative excess weight, and rate of weight loss were significant predictors (p<0.05) in this univariate analysis. However, the post-operative period, pre-operative weight, and BSSQ-eating behaviour were also included in the multivariate analysis because their p values almost reached significance at p<0.05. A p-value of 0.2 has been suggested for use in small sample sized studies (Sipsma *et al.*, 2011).

The multivariate model (Table 5), adjusted for age and gender, explained 78.8% of the variance to achieve a higher EWL post-bariatric surgery (R^2=0.788, F(8)=19.52, p<0.001). This result showed that pre-operative weight (p=0.030) and BMI (p=0.037), adherence to eating behaviour recommendations (BSSQ-eating behaviour) (p=0.025), and rate of weight loss (p<0.001) were significant predictors of EWL post-bariatric surgery (Table 4). The lower pre-operative weight of –1.580 (95% CI: –2.69, –0.14) and BMI of –1.398 (95% CI: –7.95, –0.27), greater rate of weight loss of 1.045 (95% CI: 37.35, 60.46) and adherence to eating behaviour recommendations of 0.177 (95% CI: 0.03, 0.43) predicted greater EWL post-bariatric surgery.

Table 4. Univariate regression between the predictors and percentage of excess weight loss following bariatric surgery

Variable	β	*SE*	*p-value*	*OR (95% CI)*
Age	–0.430	0.41	0.301	–0.148 (–1.26, 0.40)
Gender	–5.550	7.85	0.483	–0.101 (–21.32, 10.22)
Post-operative period	–0.819	0.43	0.061†	–0.264 (–1.68, 0.04)
Pre-operative weight	–0.215	0.12	0.089†	–0.241 (–0.47, 0.03)
Preoperative BMI	–0.987	0.40	0.016*	–0.336 (–1.78, –0.19)
% Excess weight pre-operative	–0.302	0.14	0.039*	–0.290 (–0.59, –0.16)
Rate of weight loss	19.773	6.06	0.002*	0.423 (7.60, 31.94)
Total BECK	–0.306	0.32	0.343	–0.135 (–0.95, 0.34)
Total BES	–0.656	0.52	0.217	–0.176 (–1.71, 0.40)
Total BSSQ	0.343	0.40	0.396	0.121 (–0.46, 1.15)
BSSQ – Protein	0.230	0.17	0.190	0.187 (–0.12, 0.58)
BSSQ – Eating behaviour	0.333	0.18	0.067†	0.258 (–0.02, 0.69)
BSSQ – Water intake	–0.065	0.17	0.711	–0.053 (–0.41, 0.28)
BSSQ – Physical activity	0.158	0.15	0.310	0.145 (–0.15, 0.47)
BSSQ – Vitamin intake	–0.006	0.11	0.956	–0.008 (–0.22, 0.21)
BSSQ – Fruit, vegetables, whole grain	0.016	0.18	0.927	0.013 (–0.34, 0.37)
Total support	–0.128	0.15	0.391	–0.123 (–0.43, 0.17)
Family support	–0.152	0.13	0.261	–0.160 (–0.42, 0.12)
Non-family support	–0.027	0.16	0.867	–0.024 (–0.35, 0.30)

**p* value<0.05, significant in univariate regression analysis
†were included in multivariate regression analysis

Table 5. Multivariate regression between the predictors and percentage of excess weight loss following bariatric surgery

Variable	β	*SE*	*p value*†	*OR (95% CI)*
Post-operative period	0.503	0.30	0.097	0.162 (–0.09, 1.10)
Pre-operative weight	–1.415	0.63	0.030*	–1.580 (–2.69, –0.14)
Pre-operative BMI	–4.105	1.90	0.037*	–1.398 (–7.95, –0.27)
% Excess weight pre-operative	1.918	1.27	0.139	1.845 (–0.65, 4.48)
Rate of weight loss	48.905	5.73	<0.001**	1.045 (37.35, 60.46)
BSSQ – Eating behaviour	0.228	0.10	0.025*	0.177 (0.03, 0.43)

**p*-value<0.05 and ***p* value<0.001 significant in multivariate regression analysis
†p-value by multiple linear regression adjusted to age and gender
SE, standard error; *CI*, confidence interval

DISCUSSION

As with other studies (Alexandrou *et al.*, 2015; Himpens, Dobbeleir & Peeters, 2010), ours also found that the EWL percentage decreased as the post-operative years increased. The highest mean EWL percentage was observed among participants who were in their second post-operative year. In addition, the output from the Kaplan-Meier analysis showed that the minimum time for participants to achieve a 50% EWL was approximately 8 months. The current study also discovered that the difference in the rate of weight loss between the successful and the unsuccessful weight loss maintainers groups was only observed to start from 6 months after the surgery. Drastic weight loss begins immediately following bariatric surgery and continues for 6 to 12 months (which is also known as the post-operative honeymoon period). The initial weight loss occurs without any effort from the patient due to the forced reduction of food intake because the stomach size has been reduced, and also due to the side effects of surgery, such as vomiting and food intolerance (Lynch, 2016). Subsequently, weight stabilisation and the inactive weight loss period begin 18 to 24 months post-bariatric surgery (Jones, Cleator & Yorke, 2016). Hence, the current study was conducted among post-bariatric patients who had undergone surgery at least 2 years ago.

The pre-operative weight, BMI, rate of weight loss and adherence to eating behaviour recommendations were significant predictors of greater EWL after bariatric surgery when adjusted for age and gender. The pre-operative weight had the greatest significant influence on predicting successful weight loss in the multivariate model as reduction in 1 kg of pre-operative weight will increase EWL by 1.6%. Our findings on pre-operative weight and BMI as predictors of successful weight loss are aligned with those of previous studies (Fox *et al.*, 2015; Obeidat & Shanti, 2016; Steinbeisser, McCracken & Kharbutli, 2017). The impact of pre-operative weight on enhancing weight loss after surgery remains controversial and is believed to be multifactorial (Steinbeisser *et al.*, 2017). Patients who successfully lost weight during the pre-operative period might have had more motivation to follow the dietary and lifestyle recommendations and thus be more likely to achieve successful weight loss and maintain it (Gerber *et al.*, 2016). Furthermore, a greater pre-operative weight reduction was associated with a reduced liver size, which could then reduce the risk of complications during surgery by reducing the risk of intra-operative bleeding from liver injury (van Wissen *et al.*, 2016). Therefore, improvements in pre-operative weight loss regimens are needed to promote successful post-operative weight loss. Further study is needed to analyse the contribution of pre-operative weight to post-operative weight loss.

In this study, the higher rate of weight loss also predicted greater EWL post-bariatric surgery. The rate of weight loss decreased as the time after surgery increased. This reduction might be related to reduction in the compliance of patients to dietary recommendations (Finkler, Heymsfield & St-Onge, 2012). Moreover, early post-operative weight loss significantly predicted greater weight loss at 2 years after bariatric surgery (Obeidat & Shanti, 2016). Post-bariatric surgery care requires patients to make significant lifestyle changes that involve their eating behaviour and physical activity (Liu, 2016). Dietary recommendations for the period following bariatric surgery are designed to aid patients in achieving maximal weight loss and in reducing the risk of post-surgical complications. Thus, dietary adherence is one of the most important factors for the long-term success of bariatric surgery (McGrice & Don Paul, 2015). The lack of adherence to nutritional guidelines is associated with insufficient weight loss post-operatively, while self-reported adherence to the post-operative diet at week 20 was associated with increased weight loss at post-operative week 92 (Junior, do Amaral & Nonino-Borges, 2011). The current study's findings regarding the importance of adherence to eating behaviour recommendations reflects the crucial role of dietitians in managing the nutrition of bariatric surgery patients during both the pre- and post-operative periods (Sharman *et al.,* 2017). Patients need to go through pre-operative weight loss regimens and maintain their weight loss by modifying their previous dietary and lifestyle practices. Hence, to sustain the dietary and lifestyle modifications, long-term dietetic care is required (Jastrzębska-Mierzyńska *et al.*, 2015).

A limitation of this study was that most of the latest weight data were self-reported. Only the perceived adherence of participants to the dietary recommendations was reported, and their dietary intake was not measured. As such, a comparison between perceived adherence of participants with their actual practice could not be made. In addition, a successful post-bariatric surgery outcome should not solely focus on weight loss but should also include the improvement of the co-morbidity status. However, this current study does not report on the status of co-morbidities.

CONCLUSION

The success of weight loss after bariatric surgery was reflected by the percent EWL. The current study demonstrated that lower pre-operative weight, BMI, higher rate of pre-operative weight loss and adherence to eating behaviour recommendations could significantly result in a greater percent EWL, when adjusted for age and gender. The post-operative information in this paper provides useful insights for healthcare professionals to potentially improve patient care and maximise the benefits of bariatric surgery for each patient.

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Authors' contributions

FHM, conducted the study, data analysis, prepared the draft of the manuscript and reviewed it; SS, principal investigator, conceptualised the study and reviewed manuscript; NRK, led the data collection at UKMMC and reviewed the manuscript; MAO, assisted in data analysis and interpretation and reviewed the manuscript; NR, advised on methodology, assisted in data collection and reviewed the manuscript; RR, assisted in data interpretation and reviewed the manuscript.

Conflict of interest

The authors declared that they had no conflict of interest.

Non-standard abbreviations used

BDI, Beck Depression Inventory; BES, Binge Eating Scale; BMI, body mass index; BSSQ, Bariatric Surgery Self-Management Questionnaire; DUSOCS, Duke Social Support and Stress Scale; EWL, excess weight loss; TWL, total weight loss; UKMMC, Universiti Kebangsaan Malaysia Medical Centre.

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Diabetes literacy and knowledge among patients with type 2 diabetes mellitus attending a primary care clinic in Seremban, Malaysia

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ABSTRACT

Introduction: Good health literacy and knowledge are associated with improved outcomes in diabetes. The purpose of this study was to determine diabetes-specific literacy and knowledge levels, and its associated socio-demographic factors, among adults with type 2 diabetes mellitus (T2DM). **Methods:** This cross-sectional study was conducted among 196 adults from the Indian, Chinese, and Malay ethnic groups with T2DM who attended a primary care clinic in Seremban, Malaysia. The Literacy Assessment for Diabetes and Diabetes Knowledge Test 2 were used to assess diabetes-specific literacy and knowledge, respectively. **Results:** The majority of participants (75.0%) had literacy scores that corresponded to Ninth Grade Level but only 3.6% of participants had a good knowledge of diabetes. Literacy scores explained up to 19.8% of the variance in knowledge scores (r=0.445, p<0.01). Indian participants had the lowest literacy and knowledge scores when compared to Chinese and Malays (p<0.05). Participants with higher education had better literacy and knowledge scores (p<0.05). Educational level was more likely than ethnicity to predict both literacy and knowledge scores (p<0.001), while gender and age did not significantly predict either score. The majority of participants could answer general questions about physical activity, diabetes-related complications and healthy eating. Knowledge of diabetes and its relation to specific foods and the effect of diet on glucose control were limited among the participants. **Conclusion:** Education and ethnicity were associated with literacy and knowledge on diabetes. There existed a deficit of diabetes-related nutrition knowledge among the participants. These findings may help healthcare providers tailor individualised patient educational interventions.

Keywords: Diabetes literacy, diabetes knowledge, type 2 diabetes

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INTRODUCTION

Malaysia has the highest prevalence of diabetes mellitus (DM) among the 13 countries in the Western-Pacific region (Whiting *et al.*, 2011). Over a period of 10 years, the prevalence of type 2 diabetes mellitus (T2DM) among Malaysian adults increased from 11.6% to 17.5% of the population but only <15% of these patients met their glycaemic targets of glycated haemoglobin (HbA1c) of <6.5% (IPH, 2015; Letchuman *et al.*, 2010; Mafauzy *et al.*, 2016).

Factors that contribute to poor glycaemic control in patients with diabetes include poor self-care management and medication, and a failure to adhere to dietary and lifestyle prescriptions. This behavioural inertia can be attributed to low health literacy. Health literacy is defined as the patient's capacity to obtain, understand and act upon health information (Nielsen-Bohlman, Panzer & Kindig, 2004). Health literacy affects people's ability to navigate the healthcare system, engage in self-care and chronic-disease management, and may, in turn, also affect the way knowledge about diabetes is understood and remembered for application at a later time (Powell, Hill & Clancy, 2007; Bains & Egede, 2011). Patients with diabetes who lack adequate health literacy and knowledge have a higher risk of poor glycaemic control and microvascular complications (Phillips, Rahman & Mattfeldt-Beman, 2018; Saeed *et al.*, 2018).

The current knowledge of health literacy in Malaysia may not be sufficient as previous studies were limited to the use of non-diabetes specific health literacy tools and mostly involve healthy individuals (Rajah, Hassali & Murugiah, 2019). The purpose of this study was to address this gap and to determine diabetes-specific literacy and knowledge levels, and its associated socio-demographic factors, among adults with T2DM.

MATERIALS AND METHODS

Participants

This cross-sectional study was conducted among adult patients with a confirmed diagnosis of T2DM attending a government primary care clinic in Seremban, Malaysia. The patients who were eligible for inclusion into the study were those aged 30-65 years and who could communicate in English, Malay or Mandarin. This study excluded patients who were pregnant, lactating, or who had severe diabetic complications that limited the testing of literacy and knowledge. Patients were approached in the clinic for participation based on convenience sampling from the diabetes registry of the clinic. They were then screened for eligibility and were asked to provide written informed consent before entering the study. The Medical Research and Ethics Committee of the Ministry of Health, Malaysia, provided ethical approval (NMRR-15-2231-27958) for the study.

Demographic variables and medical history data

A self-reported questionnaire was used to collect data on age, gender, ethnicity, level of education and the duration from the first diagnosis of diabetes. The most recent HbA1c values of the participants, within the previous 6 months, were obtained from the medical records.

Diabetes specific literacy

Diabetes specific literacy was assessed using the Literacy Assessment for Diabetes (LAD), which is an instrument that is used to assess the ability to read 60 nutritional and medical terms, including terms specific to diabetes that are arranged in the order of increasing complexity (Nath *et al.*, 2001). Two independent Malaysian translators back-translated the LAD from English to both Malay and Mandarin, to complement the native language used by the patients attending the clinic. A score was given for each correct pronunciation, and the raw score was then converted into one of three reading grade levels: Fourth Grade or Malaysian Primary Standard Four and below (0–20 points); Fifth to Ninth Grade or Malaysian Primary Standard Five to Secondary Form Two (21–40 points); and Ninth Grade or Secondary Form Three and above (41–60 points).

Diabetes specific knowledge

Specific knowledge of diabetes was assessed using the Diabetes Knowledge Test 2 (DKT2), which is a 14-item test of the knowledge of diabetes for people who do not use insulin (Fitzgerald *et al.*, 2016). This instrument assesses diabetes-related knowledge of physical activity, diabetes-related complications, nutritional management and glucose monitoring. The DKT2 was back-translated from English to Malay and Mandarin in a similar fashion as the LAD. A score was given for each question answered correctly, and the raw score was then converted into one of three categories: low (0-7 points); acceptable (7–10 points); and good (11–14 points) (Al-Qazaz *et al.*, 2010).

Statistical analysis

Statistical analysis was performed using the SPSS version 22 software (IBM Corp., Armonk, NY, US). Descriptive statistics (mean, standard deviation [*SD*], median, interquartile range [*IQR*], frequency and percentage participants) were used to describe the characteristics of the participants, literacy scores and knowledge scores. The independent t-test was used to compare literacy and knowledge scores between genders. The analysis of variance (ANOVA) with post-hoc Tukey's honestly significant difference (HSD) test was used to compare literacy and knowledge scores between age groups, ethnicity and educational attainment levels. A stepwise multiple regression was performed to sequentially identify the socio-demographic characteristics including gender, age, ethnicity and educational attainment levels that were most closely associated with literacy and knowledge scores, respectively. All *p*-values were two-tailed. A *p*-value of <0.05 was considered statistically significant.

RESULTS

A total of 723 patients were assessed for eligibility. Of these, a total of 515 were excluded as 417 were deemed ineligible and 98 declined to participate. Of the 208 patients who participated in the study, 196 participants provided complete data and were included in the analysis (Figure 1). The participants had a mean±*SD* age of 55.6±7.7 years. They were predominantly women (56.1%), with secondary school education (61.2%) and were of Chinese or Indian ethnicity (Malay 19.1%; Chinese 31.1%; Indian 49.0%). The median (*IQR*) duration of diagnosis with diabetes was 8.0 (9.0) years with a median (*IQR*) HbA1c of 8.1 (2.7) %.

Diabetes literacy and knowledge scores

The mean diabetes literacy score of the participants as measured by the LAD was 43.8±19.6 (mean±*SD*) points out of a possible maximum of 60 points. The majority had scores corresponding to the Ninth Grade Level (Year 9) or Malaysian secondary education of Form Three (< Fourth Grade Level or Malaysian Primary Standard Four, 16.8%; Fifth to Ninth Grade Level or Malaysian Primary

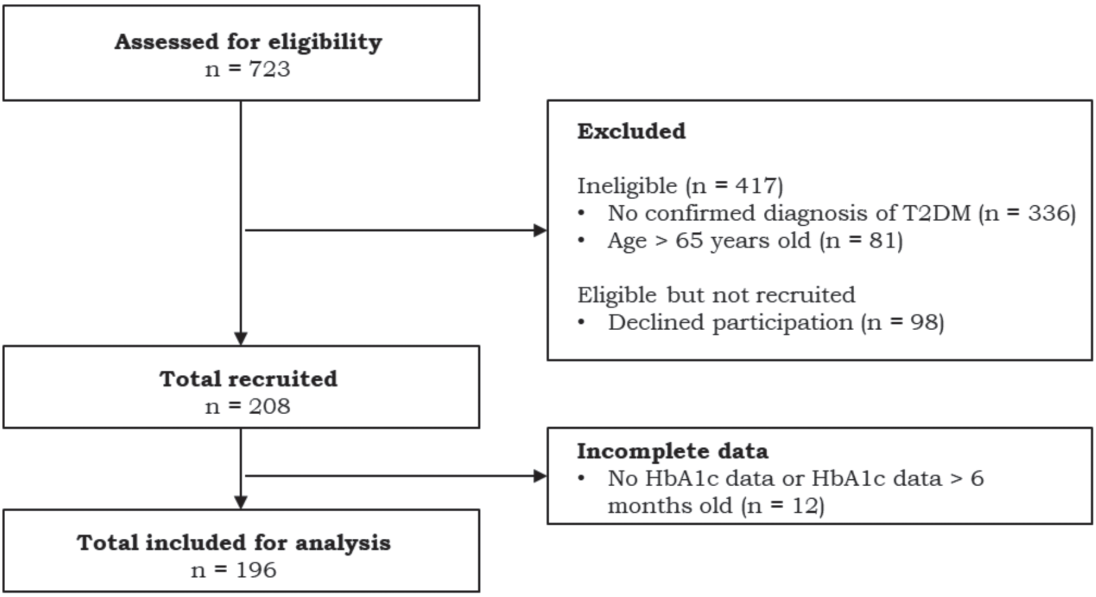

Figure 1. Flow diagram for the selection of participants of the study

Standard Five to Secondary Form Two, 8.2%; ≥Ninth Grade Level or Malaysian Secondary Form Three, 75.0%). Knowledge of diabetes as measured by the DKT2 was 6.8±2.6 (mean±*SD*) points out of a possible maximum of 14 points, and only 3.6% of participants were classified as having a good knowledge of diabetes (poor 42.9%; average 53.6%; good 3.6%). LAD scores and DKT2 scores were significantly correlated, with the former explaining up to 19.8% of the variance in the latter (r =0.445, r^2=0.198, p<0.01).

Table 1 displays the diabetes literacy and knowledge scores by participant characteristics. There was a statistically significant difference in literacy and knowledge scores between ethnicities as determined by ANOVA (p<0.01). A Tukey post-hoc test revealed that Indians had significantly lower literacy and knowledge scores compared to Malays and Chinese (p<0.05) and that there was no significant difference between Malays and Chinese (literacy: p=0.630; knowledge: p=0.919). In addition, there was a statistically significant difference in literacy and knowledge scores between participants of different educational levels as determined by ANOVA (p<0.001). For literacy scores, the Tukey post-hoc test showed that this difference was significant between all educational levels (p<0.05) except for between no formal and primary education (p=0.931), and secondary and tertiary education (p=0.285). For knowledge scores, the Tukey post-hoc test showed that this difference was significant between all educational levels (p<0.05) except for between no formal and primary education (p=1.000), and no formal and secondary education (p=0.471).

The stepwise multiple regression showed that educational level was more likely than ethnicity to predict both literacy and knowledge scores, while gender and age did not predict either literacy or knowledge scores (Table 2). There was no interaction among the characteristics of age, gender, ethnicity,

Table 1. Diabetes literacy and knowledge scores by participant characteristics (N=196)

Characteristics	*Literacy scores (Mean±SD)*	*p-value*	*Knowledge scores (Mean±SD)*	*p-value*
Gender				
Women (n=110)	43.3±19.9	0.713	6.7±2.6	0.347
Men (n=86)	44.4±19.4		7.0±2.5	
Age group				
30–39 years (n=8)	42.8±19.7		6.1±2.2	
40–49 years (n=30)	39.6±22.2	0.313	6.8±2.4	0.877
50–59 years (n=83)	42.6±20.4		6.9±2.5	
60–65 years (n=75)	46.9±17.5		6.8±2.8	
Ethnic background				
Malay (n=39)	50.7±10.4[b]	0.002	7.5±2.4[a]	0.005
Chinese (n=61)	47.1±19.0[a]		7.3±2.3[a]	
Indian (n=96)	38.9±21.7[a,b]		6.2±2.7[a]	
Level of education				
No formal (n=5)	26.6±24.9[a,b]		5.6±2.9[a]	
Primary (n=57)	31.6±24.0[c]	<0.001	5.6±2.3[c]	<0.001
Secondary (n=120)	48.7±14.4[a,c]		7.2±2.5[a,c]	
Tertiary (n=14)	57.6±3.9[b,c]		9.2±1.6[a,c]	

The same alphabets denote significant difference: a = $p<0.05$; b = $p<0.01$; c = $p<0.001$

and educational level. In the analysis for literacy scores, level of education and ethnicity were significantly related to literacy scores F (2,193)=33.417, $p<0.001$. The multiple correlation coefficient was 0.507 and 25% of the variance of literacy scores was accounted for by the level of education and ethnicity. The regression equation for predicting literacy scores was: predicted literacy scores = 8.220 + 0.469(educational level) + 0.250(ethnicity). In the analysis for knowledge scores, the level of education and ethnicity were significantly related to knowledge scores F (2,193)=23.417, $p<0.001$. The multiple correlation coefficient was 0.442 and 18.7% of the variance of knowledge scores was accounted for by the level of education and ethnicity. The regression equation for predicting knowledge scores was: predicted knowledge scores = 2.729 + 0.397(educational level) + 0.242(ethnicity).

Table 2. Socio-demographic variables most closely associated with literacy and knowledge scores (N=196)

Sociodemographic variables	*Literacy scores*				*Knowledge scores*			
	β	*SE*	*t*	*p-value*	*β*	*SE*	*t*	*p-value*
Education[†]	14.68	1.95	7.51	<0.001	1.62	0.27	6.11	<0.001
Ethnicity[†]	5.58	1.39	4.00	<0.001	0.70	0.19	3.72	<0.001
Gender	0.11		1.76	0.080	-0.05		0.74	0.460
Age	0.09		1.44	0.151	-0.01		-0.20	0.843

[†]Variables included in reduced models
Reduced model, literacy scores: F (2,193) = 33.417, $p<0.001$ adjusted R^2=0.250
Reduced model, knowledge scores: F (2,193) = 23.417, $p<0.001$ adjusted R^2=0.187

Table 3. Item analysis of the diabetes knowledge test of participants (N=196)

Items	*Diabetes knowledge tested*	*% Correct*
Physical activity		
9	Effect of exercise on blood glucose	62.2
Diabetes-related complications		
14	Identification of complications – eye, kidney, nerve	66.8
11	Diabetes self-care practice – foot care	65.3
12	Prevention of macrovascular complications – heart disease	63.3
13	Detection of microvascular complications – nerve disease	56.6
10	Effect of infection on blood glucose levels	10.7
Nutritional management		
1	Description of diabetes diet and healthy eating	61.7
2	Identification of carbohydrate-rich foods	49.0
3	Identification of high-fat foods	33.7
8	Dietary management of hypoglycaemia	28.1
7	Effect of unsweetened fruit juice on blood glucose	24.5
4	Identification of "free food"	23.0
Glucose monitoring		
6	Self-monitoring of blood glucose	54.6
5	Glucose testing – HbA1c	36.2

Diabetes knowledge – item analysis

Table 3 shows the number of correct responses to each question of the DKT2. More than 60% of the participants were able to correctly answer the question regarding physical activity (Item 9). On the subject of diabetes-related complications, >60% of the participants correctly answered questions regarding identification of complications (Item 14), diabetes self-care practice (Item 11), prevention of macrovascular complications (Item 12), and detection of microvascular complications (Item 13). However, only 10.7% of the participants correctly identified that an infection will most likely raise blood glucose (Item 10).

Responses to questions on the nutritional management of diabetes indicated that the majority of participants (61.7%) correctly answered the question on diabetes diet and healthy eating (Item 1). However, they had limited knowledge about food groups and the effect of food on blood glucose. While 49.0% of the participants could correctly identify carbohydrate-rich foods (Item 2), only 33.7% of the participants could correctly identify low-fat milk as being highest in fat among carbohydrate-rich food such as orange juice, corn, and honey (Item 3). The participants also had poor knowledge of hypoglycaemia management as only 28.1% correctly identified food or beverage portions containing 15 grams of simple carbohydrates (Item 8). About a quarter of participants (24.5%) correctly indicated that unsweetened fruit juices increase blood glucose (Item 7) and only 23.0% of the participants correctly identified that 'free food' (food items on the diabetes exchange list that are very low in calories and contain a very small amount of carbohydrates) contains <20 calories per serving (Item 4).

On the subject of diabetes monitoring, 54.6% of the participants correctly indicated that blood glucose as opposed to urine checking was the better method for checking glucose at home (Item 6). However, only 36.2% of the participants correctly knew that HbA1C was a measure of average blood glucose levels for the past 6-12 weeks (Item 5).

DISCUSSION

The socio-demographic characteristics of the participants from this study mirrored that which was seen in the registry data of the study site. However, the ethnic composition of participants in this study differed from the patient demographics in hospital-based outpatient centres across Malaysia. The participants in this study were predominantly of Indian or Chinese ethnicity. In contrast, the DiabCare 2013 study showed that patients with diabetes in Malaysia were mainly from the Malay ethnic group, followed by Chinese and Indian in similar proportions (Mafauzy *et al.*, 2016). Ethnicity can influence health literacy and knowledge outcomes when language and cultural differences exist between the patient and healthcare system (Nelson, Stith & Smedley, 2002). Thus care should be taken when generalising the results of this study to the Malaysian populace.

Consistent with other findings, >2/3 of the participants from this study presented with health literacy equivalent to secondary school education (Osborn, Bains & Egede, 2010; Bohanny *et al.*, 2013). This study also found that health literacy was positively associated with diabetes knowledge, echoing results from a meta-analysis on these variables (Marciano, Camerini & Schulz, 2019). This finding indicates the need to tailor diabetes education to the level of health literacy of the patient, as knowledge is associated with appropriate self-care and health outcomes (Kueh, Morris & Ismail, 2016). In this study, participants who had a lower level of education and those of Indian ethnicity had lower literacy and poorer knowledge scores when compared to patients of other ethnic groups. In Malaysia, the prevalence of diabetes is highest among Indians when compared to other ethnic groups (Rampal *et al.*, 2010). The low levels of literacy and knowledge among Indians shown in this study are of concern, as this may be a hindrance to the better management of diabetes among these patients.

Despite having adequate literacy to acquire and use health information, the participants from this study had lower diabetes knowledge scores when compared to those of other studies (Al-Qazaz *et al.*, 2010; Fitzgerald *et al.*, 2016). The participants from this study could answer general questions about physical activity, diabetes-related complications and healthy eating. However, diabetes-related knowledge of specific food groups and the effect of diet on glucose control was limited among participants of this study. These findings reflect the current diabetes education situation in Malaysia. In most hospitals, diabetes nurse-educators deliver information on the general management of diabetes and self-care practices via established Diabetes Resource Centers (Zanariah *et al.*, 2015). The provision of education on nutrition is nonetheless limited to general nutrition and healthy eating. In this study, majority of the participants could not identify food sources of carbohydrate and fat. Instead, they had misconceptions about food that could be incorporated *ad-libitum* into their diet.

Local studies on the knowledge of diabetes-related nutrition among Malaysian diabetics are scarce. However, the findings of local studies suggest that Malaysians with diabetes tend to consume a diet that is high in carbohydrate and fat (Norimah & Abu Bakar, 1993; Moy & Rahman, 2002; Chin *et al.*, 2013), hinting at a poor knowledge of diabetes-related nutrition. The lack of diabetes-related nutrition knowledge among patients is not isolated and has also been shown in other patients, for example, those from China. The study by Zijian *et al.* (2017) showed that Chinese patients with diabetes generally had a poor understanding of practices related to medical nutrition therapy. The Chinese patients who had better knowledge, attitude, and practice scores, exhibited better control of blood glucose (Zijian *et al.*, 2017). Nutrition education strategies that provide instructions beyond general healthy eating, such as carbohydrate calorie counting, have been shown to improve glycaemic control in both patients with type 1 DM and T2DM (Kitajima *et al.*, 2016; Brake, 2017). Among Malaysian adult patients with T2DM, specific nutritional education led to significant weight loss and improved HbA1C (Arasu *et al.*, 2016).

This study had several limitations. While the instruments that were used to assess literacy and knowledge levels had been validated in English-speaking populations (Nath *et al.*, 2001; Fitzgerald *et al.*, 2016), the translated Malay and Mandarin versions were not validated for use among Malaysians. As such, the results of this study may be subject to errors of measurement. Secondly, this study did not look at the access to healthcare provision, the attendance at educational classes on diabetes or consultations with diabetes nurse-educators or dietitians. Access to healthcare amenities and contact with a healthcare provider are associated with literacy and knowledge status of patients with diabetes (Fenwick *et al.*, 2013; Bailey *et al.*, 2014).

Trained interviewers administered the LAD and DKT2 tools by using face-to-face interviews in order to reduce the cognitive demand on the participants. The development of self-administered electronic tools that take into consideration literacy requirements can help reduce the resource burden of future studies in this area. Knowledge may not directly predict patient behavior but it is a prerequisite for appropriate self-care. This study, however, did not look at the association between diabetes-related literacy and knowledge, and actual self-care behaviour. Further research is needed to identify gaps between knowledge and practice that may exist among Malaysian patients with diabetes. The current burden of diabetes and its future implications warrant the need for educational programmes in diabetes that are tailored to the literacy and cultural environment of high-risk subjects as main target groups (Rampal *et al.*, 2010). In addition, the gaps in the knowledge of diabetes-related nutrition that exists among the participants of this study present an opportunity for appropriate interventions.

CONCLUSION

The participants of this study had fairly good diabetes-specific literacy to process health information. The study results also indicated that educational level and ethnicity were key factors for poor diabetes literacy and knowledge. There also existed nutrition-related knowledge deficits among the study participants. These findings should help healthcare providers tailor individualised patient education interventions.

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Authors' contributions

LCL, the principal investigator, conceptualised and designed the study, led the data collection, data analysis and interpretation, prepared the draft of the manuscript and reviewed the manuscript; WCSS, designed the study, supervised the data collection, advised on the data analysis and interpretation and reviewed the manuscript; KA, designed the study, supervised the data collection, conducted data analysis and interpretation and reviewed the manuscript; KSK, designed the study, supervised the data collection, advised on the data analysis and interpretation and reviewed the manuscript; SZA, designed the study, supervised the data collection and reviewed the manuscript.

Conflict of interest

The authors have no conflict of interest to declare.

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Existence of double burden of malnutrition among Filipino children in the same age-groups and comparison of their usual nutrient intake

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ABSTRACT

Introduction: This study aimed to determine the prevalence of underweight and overweight children in the same age-groups and if differences existed in their usual nutrients intake. **Methods**: Data were obtained from 8992 children aged 3-12 years who participated in 2013 National Nutrition Survey. Dietary intake information was collected using two days non-consecutive dietary recall. Usual intakes and distributions of energy and nutrients were estimated in pre-schoolers (3-5 years, n=2427), younger (6-9 years, n=3594) and older schoolchildren (10-12 years, n=2971) using PC Software for Intake Distribution Estimation (PC-SIDE) from Iowa State University. Energy inadequacy was assessed by the Estimated Energy Requirements (EER) method calculated using the equation of Institute of Medicine. The prevalence of nutrient inadequacy was estimated as the proportion of individuals with usual food intakes below the estimated average requirement (EAR). **Results:** The prevalence of underweight among preschool, younger and older schoolchildren was 22%, 30% and 16%, respectively, and 4%, 9% and 10%, respectively, among overweight. The average usual energy and nutrient intake of underweight was significantly lower than overweight. The major source of energy of underweight and overweight was from carbohydrates. However, contribution of fats to total energy was higher among overweight. Most nutrients were below EAR in underweight while only folate (50-79%) and calcium (58-84%) in overweight. **Conclusion:** The double burden of malnutrition co-exists in children of the same age-groups with higher prevalence nutrient inadequacies in underweight children. Percentage of fat contribution to energy intake was higher among overweight than the underweight.

Keywords: Double burden of malnutrition, usual nutrient intake, Filipino children, age-groups

INTRODUCTION

Rapid changes in diets and lifestyles have occurred in developing countries around the world, as a result of the general improvement of incomes, increasing industrialisation, urbanisation and globalisation (Bishwajit, 2015). Dietary patterns began to shift towards preference for processed foods, the use of edible oils and sugar-sweetened beverages. The intake of legumes, fruits and vegetables has been replaced by high intake of refined carbohydrates, added sugars, fats and foods from

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animal sources. All these, together with reduced physical activities, have given rise to a state of nutritional transition (Popkin, Adair & Ng, 2012).

In the Philippines, this transition has been reflected in changes in the proportions of macronutrient and food intake (Lipoeto, Khor & Angeles-Agdeppa, 2012). The current patterns of intake of Philippine households show an increase of energy-dense foods and of protein and fats through the consumption of animal foods. The elevated intake of cholesterol and saturated fats in the diet, coupled with sedentary lifestyles, have contributed to the increasing prevalence of overweight among adults, adolescents and children as well (Pedro, Barba & de Leon, 2008). However, on the other hand, the high rate of undernutrition, especially in children, remains the major nutritional problem in the Philippines. This has resulted in a situation where undernutrition persists together with increasing overnutrition, a phenomenon now known as the double burden of malnutrition (Florentino, Villavieja & Lana, 2002).

The double burden of malnutrition in children presents a global challenge: in 2014, about 42 million children under the age of five were overweight or obese, 156 million were affected by stunting and 50 million were affected by wasting (WHO, 2014). Among preschool children in the Philippines, the prevalence of underweight decreased slightly from 21% in 2003 to 20% in 2013 (FNRI, 2013). Meanwhile, the prevalence of overweight increased from 2% in 2003 to 5% in 2013. The same is true with schoolchildren aged 5-10 years: the prevalence of underweight in 2003 was 32% and decreased to 29% in 2013, while the prevalence of overweight increased from 6% in 2003 to 9% in 2013 (FNRI, 2013). Similar trends were seen in Indonesia and China where the prevalence rates of underweight decreased while obesity among school-aged children increased (Hanandita & Tampubolon, 2015).

This study aimed to assess the prevalence of the double burden of malnutrition among Filipino children aged 3-12 years old. We evaluated nutrient inadequacies across different age groups and weight status, to determine if there were differences in their usual nutrient intake. We also looked at how socio-economic and geographic differences affected their nutritional status.

MATERIALS AND METHODS

Study population and variables

This was a cross-sectional analytical study conducted by the Food and Nutrition Research Institute of the Department of Science and Technology (FNRI-DOST). Data was obtained from the 2013 National Nutrition Survey (NNS). A two, non-consecutive, 24-hour food recall was used to estimate the food intake of individual participants. All members of the households that were sampled were interviewed to collect data for the 1st day and only 50% of the households were randomly selected to have a 2nd day food recall data. The dietary intake of pre-schoolers (3-5 years old), younger schoolchildren (6-9 years old) and older schoolchildren (10-12 years old) and the demographic characteristics such as national identification (ID) code, age, survey weights, recorded day, weight (kg), height (m) and gender, were extracted from the 2013 NNS data set.

A total of 8,992 children were included in the study: 2,427 of the children were aged 3-5 years, 3594 children 6-9 years and 2971 children 10-12 years. The age groups were aligned with the Philippine Dietary Reference Intake (PDRI) age grouping (FNRI, 2015).

Measurements

Dietary

Face-to-face interview was conducted to obtain information on food that was consumed by an individual over the past 24 hours. The food consumption that was recorded was that starting from the time the subject woke up until bedtime. It included morning, afternoon and late evening (PM) snacks, all food items that were consumed, as well as their description including cooking methods that were used. The amount of each food item and beverage was estimated using common household measurements such as cups, tablespoons, or by size and number of pieces. The Individual Dietary Evaluation System (IDES) was used to evaluate the energy and nutrients content of food consumed by each individual. The estimation of energy and nutrients contents of foods consumed was done using the Updated Philippine Food Composition Table (PhilFCT) that contains 27 nutrients. Details in the development of the Updated PhilFCT will be presented in another publication. The information collected included the name and brand of the food items that were consumed. However, dietary supplements were not included in the survey. Thus, the amount of nutrients consumed were computed based on only the food intake.

Anthropometry

Weight was measured using the mechanical Detecto® platform beam balance scales and standing height using the Microtoise, which is an L-shaped device (head-bar) to which a spring-loaded coiled tape measure was attached. At least two measurements were obtained to take an average. Weight and height measurements were recorded to the nearest 0.1 kg and 0.1 cm, respectively. Third measurements were only taken if the difference of the two measurements in weight and height were greater than 0.3 kg and 0.5 cm, respectively.

Socioeconomic demographic

A face-to-face interview was conducted to gather data on the socio-economic and demographic variables such as dwelling and household characteristics, and assets. The wealth status of the participants was defined by proxy indicators such as household possession of vehicles, appliances, materials used for housing construction and sanitation facilities. Scores obtained from principal component analysis were used to define wealth quintiles as poorest, poor, middle, rich and richest. Locality was classified as rural and urban by the Philippine Statistical Authority (PSA).

Energy and nutrient evaluation

Energy and nutrient intakes were scanned to identify implausible values. All processes and evaluations were done for all age groups.

For the evaluation of energy intake, the ratio of daily energy intake to the estimated energy requirement (EER) was calculated for each person per day and then transformed to the logarithmic scale to remove the outliers which defined as values that were < -3SDs and > +3SDs in each age group.

For the evaluation of micronutrient intakes, excessive intakes were substituted by a random value generated from the uniform distribution in the interval of lower bound equal to the 95th percentile of observed intake and upper bound equal to 1.5 times 99th percentile. Excessive micronutrient intakes were defined as those that exceed to 1.5 times the 99th percentile of the observed intake distribution of the corresponding age group.

The distribution of vitamin B_{12}, C and D for all age groups was highly skewed. Hence, we generated and added a small amount of random noise [N~ (0.35, 0.05)] to vitamin B_{12}, C and D intakes to adjust the intakes and rerun the analysis.

Data and statistical analysis

PC Software for Intake Distribution Estimation (PC-SIDE) version 1.0 was used to compute the mean usual intake distributions of energy and nutrients listed in Table 2 and the prevalence of inadequate and excessive intakes. This software was produced by the researchers of the Department of Statistics at Iowa State University (ISU) in 2001. This programme called the ISU Method (Nusser *et al.*, 1996) has been used to estimate the distributions of usual intake of nutrients, foods consumed almost daily, and other dietary components dietary components. In addition, this programme adjusts the biomarker data for within-person variability (http://www.side.stat.iastate.edu).

The PDRI was used to evaluate the nutrient inadequacy and excessive intake to determine whether the foods that were consumed provided adequate nutrients to guarantee sufficient growth and development. PDRI was stratified generally by gender. The estimated average requirement (EAR) for male and female were computed for each nutrient to assess the nutrient inadequacy of children.

Prevalence of inadequacy in a group is estimated as the proportion of individuals with usual intakes below the EAR. All nutrients with EARs were assessed using the EAR cut-point method. Nutrients without EAR were saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), dietary fibre, total sugars, vitamin D, vitamin E, magnesium, potassium and sodium (FNRI, 2015).

Total energy intakes were assessed against EER. The EER for each respondent was calculated using the Institute of Medicine's (IOM) equation that takes into account age, sex, body weight (kg), height (m), and physical activity level (PAL). Physical activity of children was assumed as follows: pre-schoolers were sedentary, younger schoolchildren were low active and older schoolchildren were active.

The Acceptable Macronutrient Distribution Ranges (AMDR) reflect the values for carbohydrates (55-79%), protein (6-15%) and fats (15-30%) which are expressed as a percentage of recommended total energy intake of an individual. Values below the recommended range for the specific macronutrient are considered inadequate or low while those above are considered excessive. The derived values reflect the amount of each macronutrient in the total energy intake of the individual to prevent risk of chronic diseases while providing other essential nutrients.

The independent *t*-test and equality of proportion were used to determine the difference the mean intake and prevalence of inadequacy between nutritional statuses of children. For multiple comparisons, we used the Bonferroni correction for adjustment. All *p*-values were 2-tailed and differences were considered statistically significant at $p<0.05$. The nutritional status of children was classified as either underweight or overweight. Pre-schoolers (3-5 years old) and younger schoolchildren (6-9 years old) were classified as underweight if weight-for-age *z*-score (WAZ) was < -2SD. Among older children aged 10-12 years old, underweight was measured using BMI-for-age *z*-score (BAZ) < -2SD. Pre-schoolers and younger schoolchildren were considered overweight if BMI was > 2SD (BAZ > 2SD) while for the older schoolchildren, BAZ > 1SD was overweight and BAZ > 2SD was considered obese. In this paper, overweight and obesity in this age group are reported as overweight.

Ethical review

The 8th NNS Philippines 2013 was submitted to the FNRI Institutional Ethics Review Committee (FNRI-IERC) for clearance. But since it was mandated to define the nutritional status of Filipinos, clearance of the said survey was not necessary. Written consent to participate in the 8th NNS was obtained from the respondents and subjects (through the mother or guardian for children <10 years old) prior to the interview and other measurements. The informed consent form explained the background and objectives of the survey, the data collection procedures that were involved, the risks (i.e. any undesirable effect that may result or invasion circumstances, e.g. expected duration of the interview with respondent) and benefits of participation, confidentiality of information, the option to withdraw without penalty or consequences and the respondent's written consent.

RESULTS

Table 1 shows the demographics of the study population. The prevalence of underweight among pre-school children, younger and older schoolchildren was 22%, 30% and 16%, respectively, and that of overweight was 4%, 9% and 10%, respectively. The proportions of male and female children were similar in all age groups. The mean age for pre-schoolers, younger school children and older schoolchildren were 4.5, 8.0 and 11.5 years, respectively.

There were significant differences in the socio-economic status and locale of the underweight and overweight children in all age groups. Most of the underweight pre-schoolers (39%), younger (38%) and older schoolchildren (26%) were from the poorest households while overweight pre-schoolers (46%), younger (44%) and older schoolchildren (47%) were from the richest. Most of the underweight pre-schoolers (54%), younger (59%) and older (46%) schoolchildren were from rural area while overweight pre-schoolers (61%), younger (68%) and older (68%) schoolchildren were from urban areas.

Energy

The energy intake of underweight children was significantly lower than the intake of overweight children in all age groups (p<0.05). For underweight children, the mean usual intake of pre-schoolers, younger, and older schoolchildren were 873±1; 1098±11; and 1406±21 kcal, respectively. The average energy intake of the underweight children was 14%, 16% and 19% lower than EER among pre-schoolers, younger schoolchildren and older schoolchildren, respectively. The mean usual intakes of pre-schoolers, younger, and older schoolchildren were 1310±67; 1651±30; and 1966±27 kcal, respectively. The average energy intake of overweight children pre-schoolers was 4% higher than EER, 6% lower among younger schoolchildren and 27% lower among older schoolchildren (Table 2).

Macronutrients

The macronutrient intake of underweight children, namely, carbohydrate, protein, total fats, as well as dietary fibre, sugar, SFA, MUFA, and PUFA was significantly lower than the intake of overweight children for all age groups (p<0.05). The inadequate intake of protein among underweight was 16%, 21% and 23%, among pre-schoolers, younger schoolchildren and older schoolchildren, campared to that for the overweight which was 6%, 2% and 1%, respectively (Table 2).

As percentage of total energy

Fat and protein intakes for all age groups, as percentages of total energy, of underweight children were

Table 1. Percentage distribution of children by socio-economic and demographic variables and age group

Variable	*Pre-schooler* *n=2427*		*Younger schoolchildren* *n=3594*		*Older schoolchildren* *n=2971*		*Total* *n=8992*
Age, year (Mean±SE)	4.50±0.02		8.00±0.02		11.50±0.02		7.90±0.03
Gender (%)							
Male	48.2		50.8		52.3		50.4
Female	51.8		49.2		47.7		49.6
Nutritional status (%)							
Underweight	22.0		30.0		16.0		
Overweight	4.0		9.0		10.0		
	UW† *n=543*	*OW*‡ *n=62*	*UW*† *n=1081*	*OW*‡ *n=286*	*UW*† *n=424*	*OW*‡ *n=261*	
Family economic status [percentages (SE)]							
Poorest	39.0 (0.02)	6.4 (0.03)	38.4 (0.01)	5.3 (0.01)	26.2 (0.02)	7.7 (0.02)	
Poor	27.2 (0.02)	10.6 (0.04)	25.1 (0.01)	14.0 (0.02)	21.4 (0.02)	10.7 (0.02)	
Middle	18.3 (0.02)	12.5 (0.04)	20.0 (0.01)	11.7 (0.02)	21.4 (0.02)	13.7 (0.02)	
Rich	10.5 (0.01)	24.8 (0.05)	10.9 (0.01)	24.6 (0.03)	19.3 (0.02)	20.9 (0.03)	
Richest	5.0 (0.01)	45.7 (0.06)	5.6 (0.01)	44.4 (0.03)	11.7 (0.01)	47.0 (0.03)	
p-value	<0.001*		<0.001*		<0.001*		
Locality [percentages (SE)]							
Rural	54.0 (0.02)	38.6 (0.06)	58.9 (0.01)	31.7 (0.03)	46.4 (0.02)	32.5 (0.02)	
Urban	46.0 (0.02)	61.4 (0.06)	41.1 (0.01)	68.3 (0.03)	53.6 (0.02)	67.5 (0.03)	
p-value	0.038*		<0.001*		<0.001*		

†UW is the proportion of underweight children
‡OW is the proportion of overweight children
*significantly different from overweight at $p<0.05$

significantly lower than the intakes of overweight (p<0.05). However, the carbohydrate intake of the underweight was significantly higher than that of the overweight (p<0.05). For underweight children, inadequate intake of fat as percentage of total energy was 34% among pre-schoolers, 52% among younger schoolchildren and 47% among older schoolchildren. The inadequate intake of carbohydrates as percentage of total energy was 5% among pre-schoolers; 2% among younger and older schoolchildren. For the overweight children, inadequate intake of fat as percentage of total energy 7% among pre-schoolers, 11% among younger schoolchildren and 21% among older schoolchildren. Inadequate intake of carbohydrates was 24% among pre-schoolers and 6% among younger and older schoolchildren. Protein inadequacy was not observed among children for all age groups (Table 3).

Vitamins and minerals

Vitamin intakes were significantly lower than intakes of overweight children for all age groups. The mineral intake of underweight children was significantly lower than that of the overweight children for all age groups. The mean intake of magnesium and sodium of underweight and overweight children for all age groups were above the recommended intake per day (Table 2 and FNRI, 2015). A high prevalence of inadequate mineral intake was observed for both underweight and overweight children (Table 3).

A high prevalence of inadequate intake was observed for underweight children: vitamin A was 61% among younger schoolchildren and 63% among older schoolchildren; thiamine was 56% among pre-schoolers, 64% among younger schoolchildren and 74% among older schoolchildren; riboflavin was 57% among pre-schooler, 74% among younger schoolchildren and 83% among older schoolchildren; vitamin C was 64% among pre-schoolers, 67% among younger schoolchildren and 90% among older schoolchildren; folate was 79% among pre-schoolers, 68% among younger schoolchildren and 91% among older schoolchildren. For overweight children, inadequate intake of folate was 50% among pre-schoolers and younger schoolchildren and 79% among older schoolchildren; and vitamin C was 59% among younger schoolchildren and 71% among older schoolchildren.

High prevalence of inadequate intake was observed for underweight children: calcium was 92%, 96% and 95% among pre-schoolers, younger schoolchildren and older schoolchildren, respectively; iron was 89%, 84% and 97% among pre-schoolers, younger schoolchildren and older schoolchildren, respectively; phosphorus was 52% and 96% among pre-schoolers and older schoolchildren, respectively; and zinc was 64% among pre-schoolers and 54% among younger schoolchildren. For overweight children, inadequate intake of calcium was 58% among pre-schoolers, 84% among younger schoolchildren and 79% among older schoolchildren; iron was 58% among pre-schoolers and 85% among older schoolchildren; and phosphorus was 72% among older schoolchildren (Table 2).

Prevalence of inadequacy by location

Table 4 presents the prevalence of inadequacy of energy and nutrients based on the location of their residence, it being either rural or urban.

Macronutrients

Prevalence of inadequacy of protein in children who were 3 to 12 years was significantly higher in rural areas in both underweight and overweight. When macronutrients were considered as percentage of the total energy, it was seen that fat inadequacy was higher

Table 2. Mean usual intakes of energy, nutrients and energy intakes from macronutrients of children aged 3 to 12 years by nutritional status [presented as mean (SE)]

Energy and nutrients	*Pre-schooler*		*Younger schoolchildren*		*Older schoolchildren*	
	UW†	*OW*‡	*UW*†	*OW*‡	*UW*†	*OW*‡
	n=543	*n=62*	*n=1081*	*n=286*	*n=424*	*n=261*
Energy (kcal)	874 (13)*	1310 (67)	1098 (11)*	1651 (30)	1406 (21)*	1966 (27)
EER	1020 (2)	1256 (20)	1310 (3)	1763 (18)	1740 (12)	2705 (37)
Macronutrients						
Carbohydrate (g/d)	147.9 (2.1)*	187.9 (9.7)	196.2 (2.1)*	266.4 (4.9)	249.8 (3.9)*	323.4 (4.9)
Protein (g/d)	27.6 (0.5)*	41.7 (2.3)	33.9 (0.4)*	53.0 (1.0)	43.3 (0.6)*	62.7 (0.9)
Total fat (g/d)	19.1 (0.5)*	37.1 (2.3)	19.4 (0.3)*	40.7 (1.0)	26.7 (0.8)*	44.9 (0.10)
SFA (g/d)	8.1 (0.2)*	15.9 (1.4)	8.4 (0.2)*	17.0 (0.6)	12.2 (0.4)*	19.8 (0.5)
MUFA (g/d)	6.6 (0.2)*	12.9 (1.1)	6.0 (0.1)*	14.0 (0.8)	8.9 (0.3)*	14.9 (0.4)
PUFA (g/d)	3.1 (0.1)*	5.4 (0.4)	3.0 (0.1)*	5.8 (0.2)	4.1 (0.1)*	6.9 (0.1)
Dietary fibre (g/d)	4.4 (0.1)*	5.0 (0.3)	5.9 (0.1)*	7.0 (0.1)	6.7 (0.1)*	8.5 (0.1)
Total sugars (g/d)	23.7 (0.7)*	41.4 (3.5)	21.9 (0.4)*	35.1 (1.0)	25.9 (0.7)*	33.0 (0.7)
As percentage of total energy						
Total Fat (%)	18.3 (0.3)*	25.9 (0.9)	15.3 (0.2)*	21.9 (0.3)	16.2 (0.3)*	20.4 (0.4)
Protein (%)	12.7 (0.1)*	13.0 (0.3)	12.6 (0.1)*	13.1 (0.1)	12.6 (0.1)*	13.2 (0.1)
Carbohydrate (%)	69.1 (0.4)*	60.7 (1.0)	72.2 (0.2)*	65.0 (0.4)	71.2 (0.3)*	66.4 (0.4)
Vitamins						
Vitamin A (μg RE/d)	269.2 (6.2)*	430.6 (12.3)	263.3 (4.4)*	365.4 (10.2)	353.7 (8.9)*	474.1 (13.1)
Thiamine (mg/d)	0.5 (0.0)*	0.8 (0.1)	0.5 (0.0)*	0.8 (0.0)	0.6 (0.0)*	1.0 (0.0)
Riboflavin (mg/d)	0.5 (0.0)*	1.0 (0.1)	0.5 (0.0)*	0.8 (0.0)	0.6 (0.0)*	0.9 (0.0)
Niacin (mg/d)	8.0 (0.1)*	10.9 (0.6)	10.5 (0.1)*	15.8 (0.3)	13.3 (0.2)*	19.5 (0.3)
Pyridoxine (mg/d)	1.0 (0.1)*	1.2 (0.1)	1.3 (0.0)*	1.5 (0.1)	1.8 (0.04)*	1.8 (0.0)
Cobalamin (mg/d)	1.5 (0.0)*	1.8 (0.1)	2.6 (0.0)*	3.3 (0.1)	3.0 (0.1)*	3.9 (0.1)
Vitamin C (mg/d)	16.8 (0.6)*	27.4 (1.8)	20.1 (0.5)*	22.4 (0.7)	18.3 (0.6)*	28.9 (1.1)
Vitamin D (ug/d)	1.8 (0.1)*	2.4 (0.3)	2.2 (0.0)*	3.1 (0.1)	2.6 (0.1)*	3.2 (0.0)
Vitamin E (mg/d)	1.2 (0.1)*	3.3 (0.3)	2.1 (0.0)*	3.1 (0.1)	2.5 (0.1)*	3.7 (0.1)
Folate (ug/d)	116.2 (2.7)*	176.0 (11.1)	140.0 (2.3)*	170.6 (4.3)	154.5 (3.3)*	192.6 (5.2)

Table 2. Mean usual intakes of energy, nutrients and energy intakes from macronutrients of children aged 3 to 12 years by nutritional status [presented as mean (SE)] (continued)

Energy and nutrients	*Pre-schooler*		*Younger schoolchildren*		*Older schoolchildren*	
	UW†	*OW*‡	*UW*†	*OW*‡	*UW*†	*OW*‡
	n=543	*n=62*	*n=1081*	*n=286*	*n=424*	*n=261*
Minerals						
Calcium (mg/d)	235.2 (6.2)*	445.3 (36.4)	223.12 (3.3)*	312.6 (8.0)	261.6 (4.7)*	360.9 (7.4)
Iron (mg/d)	4.7 (0.1)*	7.2 (0.4)	5.8 (0.1)*	9.4 (0.2)	7.4 (0.1)*	10.7 (0.2)
Magnesium (mg/d)	82.9 (1.4)*	102.8 (6.8)	110.1 (1.3)*	142.9 (2.6)	132.0 (2.1)*	180.2 (3.1)
Phosphorus (mg/d)	424.6 (7.1)*	654.7 (44.0)	519.6 (5.7)*	772.6 (14.1)	662.2 (9.5)*	937.6 (13.9)
Potassium (mg/d)	590.7 (10.6)*	848.2 (53.3)	726.1 (7.9)*	1009.9 (17.7)	859.1 (12.5)*	1228.1 (23.8)
Selenium (µg/d)	47.5 (0.9)*	65.0 (2.8)	60.4 (0.7)*	92.4 (1.9)	78.0 (1.1)*	113.5 (1.7)
Sodium (mg/d)	647.8 (16.1)*	1005.5 (58.9)	683.3 (11.5)*	1201.0 (32.1)	847.1 (20.4)*	1263.8 (22.2)
Zinc (mg/d)	3.1 (0.1)*	5.3 (0.3)	3.6 (0.1)*	6.1 (0.1)	4.6 (0.1)*	7.4 (0.0)

Standard error <0.05 rounded to 0.0

†OW is the proportion of overweight children

‡UW is the proportion of underweight children

*significantly different from overweight, $p<0.05$

Table 3. Prevalence of inadequacies and excessive of usual nutrient intake of children aged 3 to 12 years by nutritional status [presented as percentages (standard error of usual nutrient intakes)]

Nutrients	*Pre-schooler*				*Younger schoolchildren*				*Older schoolchildren*			
	% <EAR/AMDR†		*% >AMDR/ >UL*‡		*% <EAR/AMDR*†		*% >AMDR/ >UL*‡		*% <EAR/AMDR*†		*% >AMDR/ >UL*‡	
	UW	*OW*	*UW*	*OW*	*UW*	*OW*	*UW*	*OW*	*UW*	*OW*	*UW*	*OW*
	n=543	*n=62*	*n=543*	*n=62*	*n=1081*	*n=286*	*n=1081*	*n=286*	*n=424*	*n=261*	*n=424*	*n=261*
Macronutrients												
Protein (g/d)	16.2 (1.6)*	6.0 (3.0)	-	-	21.1 (1.2)*	1.5 (1.5)	-	-	23.3 (2.1)*	1.4 (0.1)	-	-
As percentage of total energy												
Total Fat (%)	34.2 (2.0)*	6.8 (3.2)	5.5 (1.0)*	28.9 (5.8)	52.2 (1.5)*	11.1 (3.7)	2.2 (0.4)*	8.8 (3.4)	47.3 (2.4)*	21.4 (2.5)	3.4 (0.9)*	8.3 (1.7)
Protein (%)	0	0.1 (0.3)	14.9 (1.5)	17.2 (4.8)	0	0	10.8 (0.9)	12.3 (3.9)	0	0	5.6 (1.1)	9.5 (1.8)
Carbohydrate (%)	5.1 (0.9)*	24.3 (5.5)	10.7 (1.3)*	1.9 (1.7)	1.7 (0.4)*	6.4 (2.9)	17.7 (1.2)*	0.8 (1.0)	1.9 (0.7)*	6.2 (1.5)	12.8 (1.6)*	2.9 (1.0)
Vitamins												
Vitamin A (µg RE/d)	42.4 (2.1)*	0.3 (0.6)	21.8 (1.8)*	6.6 (3.2)	60.5 (1.5)*	32.3 (5.6)	0.31 (0.17)	1.2 (1.3)	62.8 (2.3)*	35.1 (3.0)	0.03 (0.1)	0.1 (0.2)
Thiamine (mg/d)	56.2 (2.1)*	24.2 (5.4)	-	-	64.1 (1.5)*	16.6 (4.4)	-	-	73.6 (2.1)*	25.5 (2.7)	-	-
Riboflavin (mg/d)	57.0 (2.1)*	23.7 (5.4)	-	-	74.1 (1.3)*	22.5 (5.0)	-	-	83.0 (1.8)*	49.4 (3.1)	-	-
Niacin (mg/d)	16.8 (1.6)*	6.7 (3.2)	3.1 (0.7)*	16.9 (4.8)	19.1 (1.2)*	1.74 (1.6)	12.9 (1.0)*	51.4 (5.9)	17.2 (1.8)*	1.1 (0.7)	6.0 (1.2)*	43.6 (3.1)
Pyridoxine (mg/d)	34.3 (2.0)*	13.7 (4.4)	0	0	31.6 (1.1)*	6.6 (3.0)	0	0	4.9 (1.0)*	0.4 (0.4)	0	0
Cobalamin (mg/d)	31.2 (2.0)*	15.9 (4.6)	-	-	6.1 (0.7)	1.9 (1.6)	-	-	4.1 (1.0)*	0.9 (0.6)	-	-
Folate (µg/d)	78.8 (1.8)*	50.0 (6.4)	-	-	67.7 (1.4)*	49.9 (5.9)	-	-	90.9 (1.4)*	79.0 (2.5)	-	-
Vitamin C (mg/d)	63.5 (2.1)*	23.7 (5.4)	0	0	66.7 (1.4)*	58.7 (5.8)	0	0	89.8 (1.5)*	70.6 (2.8)	0	0

Table 3. Prevalence of inadequacies and excessive of usual nutrient intake of children aged 3 to 12 years by nutritional status [presented as percentages (standard error of usual nutrient intakes)] (continued)

Nutrients	*Pre-schooler*				*Younger schoolchildren*				*Older schoolchildren*			
	% <EAR/AMDR†		*% >AMDR/>UL*‡		*% <EAR/AMDR*†		*% >AMDR/>UL*‡		*% <EAR/AMDR*†		*% >AMDR/>UL*‡	
	UW *n=543*	*OW* *n=62*	*UW* *n=543*	*OW* *n=62*	*UW* *n=1081*	*OW* *n=286*	*UW* *n=1081*	*OW* *n=286*	*UW* *n=424*	*OW* *n=261*	*UW* *n=424*	*OW* *n=261*
Minerals												
Calcium (mg/d)	91.7 (1.2)*	57.9 (6.3)	0	0	95.7 (0.6)*	84.3 (4.3)	0	0	95.0 (1.1)*	78.5 (2.5)	0	0
Iron (mg/d)	88.9 (1.3)*	60.0 (6.3)	0	0	84.4 (1.1)*	44.6 (5.9)	0	0	96.6 (0.9)*	85.5 (2.2)	0	0
Phosphorus (mg/d)	51.4 (2.1)*	25.7 (5.6)	0	0	29.6 (1.4)*	3.0 (2.0)	0	0	96.2 (0.9)*	72.2 (2.8)	0	0
Selenium (µg/d)	2.1 (0.6)	0.2 (0.6)	0.1 (0.1)	0.1 (0.4)	0.1 (0.1)*	0	0.4 (0.2)*	4.98 (1.83)	0	0	0	0
Zinc (mg/d)	64.0 (2.1)*	20.7 (5.1)	0*	1.0 (1.3)	54.3 (1.5)*	6.7 (3.0)	0.1 (0.1)*	1.3 (1.4)	47.8 (2.4)*	2.4 (0.9)	0	0

† % <EAR/AMDR is the proportion of children who had inadequate intake
‡ % >AMDR/ >UL is the proportion of children who had excessive intake
*significantly different from overweight at $p<0.05$

Table 4. Prevalence of inadequacies of nutrients intake of children aged 3-12 years by nutritional status and locality [presented as percentages (standard error of usual nutrient intakes)]

Nutrients	*Underweight*		*Overweight*	
	Rural n=1262	*Urban n=785*	*Rural n=244*	*Urban n=364*
Macronutrients				
Protein	28.0 (0.019)*	11.3 (0.024)	4.0 (0.027)*	1.4 (0.011)
As % of the total energy				
Fat	62.0 (0.019)*	28.9 (0.025)	27.2 (0.045)*	6.5 (0.040)
Protein	0	0	0	0
Carbohydrates	1.0 (0.005)*	5.1 (0.017)	5.0 (0.032)*	7.6 (0.004)
Vitamins				
Vitamin A	64 (0.026)	61.1 (0.031)	33.6 (0.078)*	44.3 (0.039)
Thiamin	75.1 (0.021)*	48.8 (0.023)	25 (0.062)	19.5 (0.040)
Riboflavin	78.7 (0.019)*	59.4 (0.020)	38.2 (0.038)*	30.5 (0.034)
Niacin	25.3 (0.020)*	9.5 (0.027)	3.7 (0.026)*	1.1 (0.011)
Vitamin B6	39.7 (0.020)*	21.9 (0.046)	10.6 (0.048)	8 (0.037)
Vitamin B12	8.5 (0.043)	10.6 (0.046)	1.2 (0.029)*	4.3 (0.038)
Folate	73.6 (0.022)*	79.4 (0.038)	63.8 (0.045)	57.9 (0.039)
Vitamin C	67.5 (0.030)*	72.6 (0.025)	57.7 (0.051)	60.3 (0.051)
Minerals				
Calcium	95.5 (0.013)	94.5 (0.021)	79 (0.054)	73 (0.035)
Iron	93.2 (0.015)*	81.6 (0.031)	66.1 (0.039)*	53.4 (0.031)*
Phosphorus	53.6 (0.013)*	43.7 (0.018)	30.4 (0.033)	25.9 (0.028)
Selenium	0.6 (0.003)	0.1 (0.001)	0	0
Zinc	67.5 (0.019)*	40.2 (0.025)	11.8 (0.060)*	4.7 (0.029)

*Significantly different from urban, $p<0.05$, by using hypothesis testing to compare two population proportions

in rural compared to urban areas but carbohydrate inadequacy was lower in the rural areas for both underweight and overweight.

Vitamins and minerals

For the underweight, inadequacies in vitamin B such as thiamine, riboflavin, niacin and B6 were higher than rural areas while inadequacies in folate and vitamin C was lower in rural. For the overweight, inadequacies in vitamin A and B12 were significantly lower in rural areas while inadequacies in riboflavin and niacin were significantly higher in rural.

In regard to minerals, inadequacies for the underweight in iron phosphorus and zinc were significantly higher in rural areas. For the overweight, inadequacies in iron and zinc were significantly higher in rural areas.

Table 5. Prevalence of inadequacies of nutrients intake of children aged 3 to 12 years by nutritional status and wealth quintile [presented as percentages (standard error of usual nutrient intakes)]

Nutrients	Underweight					Overweight				
	Poorest *n=798*	*Poor* *n=497*	*Middle* *n=360*	*Rich* *n=226*	*Richest* *n=104*	*Poorest* *n=45*	*Poor* *n=84*	*Middle* *n=83*	*Rich* *n=139*	*Richest* *n=245*
Macronutrients										
Protein	28.5 (0.025)[a]	22.5 (0.032)[b]	13.8 (0.041)[c,a,b]	11.6 (0.042)[d,a,b]	1.2 (0.025)[a,b,c,d]	15.5 (0.090)[a]	0.5 (0.019)[b,a]	11.0 (0.051)[c,b]	0.5 (0.011)[a,b]	1.0 (0.010)[a,c]
As % of the total energy										
Fat	74.9 (0.031)[a]	44.4 (0.037)[b,a]	26.3 (0.049)[c,a,b]	18.1 (0.057)[a,b]	7.4 (0.049)[a,b,c]	47.7 (0.073)[a]	26.9 (0.102)[b]	28.9 (0.093)[c]	10.7 (0.084)[d,a,b,c]	2.9 (0.034)[a,b,c,d]
Protein	0	0	0	0	0	0	0	0	0	0
Carbohydrates	0.4 (0.004)[a]	0.3 (0.005)[b]	2.9 (0.025)[c,a,b]	2.6 (0.028)[d,a,b]	18.6 (0.063)[a,b,c,d]	2.8 (0.043)	1.9 (0.048)[b]	1.4 (0.034)[c]	1.5 (0.043)	14.1 (0.061)[b,c,d]
Vitamins										
Vitamin A	67.2 (0.035)[a]	64.1 (0.040)[b]	62.6 (0.046)	50.9 (0.062)[a,b]	53.6 (0.070)	29.7 (0.317)[a]	57.8 (0.103)[b,a]	45 (0.064)	43.0 (0.070)[d]	28.7 (0.090)[b,d]
Thiamin	75.8 (0.024)[a]	66.3 (0.035)[b,a]	59.4 (0.044)[c,a]	48.8 (0.046)[d,a,b]	19.6 (0.102)[a,b,c,d]	60.9 (0.073)[a]	27.2 (0.084)[b,a]	27.1 (0.078)[c,a]	22.0 (0.079)[d,a]	10.3 (0.064)[a,b,c,d]
Riboflavin	85.4 (0.023)[a]	73.1 (0.032)[b,a]	62.2 (0.035)[c,a,b]	54.6 (0.036)[d,a,b]	28.7 (0.074)[a,b,c,d]	63.6 (0.086)[a]	42.9 (0.072)[b]	44.7 (0.055)[c]	29.1 (0.064)[a]	21.1 (0.053)[a,b,c]
Niacin	24.4 (0.027)[a]	18.3 (0.034)[b]	15.0 (0.043)[c,a]	7.8 (0.051)[a,b]	3.5 (0.048)[a,b,c]	9.2 (0.092)[a]	0.6 (0.021)	8.3 (0.059)[c]	0.8 (0.015)[c]	1.1 (0.013)[a,c]
Vitamin B6	33.1 (0.038)[a]	42.4 (0.031)[b,a]	32.4 (0.048)[c,b]	23.8 (0.089)[a,b,c]	17.3 (0.077)[a,b,c]	25.4 (0.113)[a]	17 (0.059)	8.4 (0.114)	6.9 (0.070)[a]	4.8 (0.041)[a]
Vitamin B12	7.9 (0.054)[a]	19.9 (0.041)[b,a]	13.2 (0.082)[c,a]	0.2 (0.024)[d,a,b]	6.2 (0.103)[b,d]	7.7 (0.177)[a]	1.2 (0.048)	6.6 (0.099)	0.0 (0.004)[a]	4.7 (0.044)
Folate	74.7 (0.024)[a]	74.7 (0.039)[b,a]	84.0 (0.084)[c,a,b]	86.8 (0.129)[d,a,b]	64.0 (0.082)[c,d]	77.2 (0.154)	56.8 (0.068)	58.8 (0.064)	71.4 (0.107)[d]	54.8 (0.041)[d]
Vitamin C	65.6 (0.061)[a]	77.5 (0.054)[b,a]	72.2 (0.078)[c]	78.6 (0.078)[d,a]	41.6 (0.106)[a,b,c,d]	11.8 (0.053)[a]	64.8 (0.097)[a]	77.6 (0.072)[c,a]	64.9 (0.163)[a]	51.9 (0.044)[a,c]
Minerals										
Calcium	96.8 (0.013)[a]	95.6 (0.025)[b]	96.0 (0.029)[c]	96.4 (0.035)	79.1 (0.088)[a,b,c]	92.2 (0.085)[a]	82.1 (0.104)	74.8 (0.066)	74.3 (0.064)	70.8 (0.040)[a]
Iron	93.4 (0.017)[a]	87.5 (0.034)[b,a]	89.7 (0.054)[c]	82.5 (0.057)[d,a]	65.6 (0.109)[a,b,c,d]	85.6 (0.086)[a]	66.1 (0.089)	61.3 (0.056)[a]	59.9 (0.057)[a]	50.9 (0.037)[a]
Phosphorus	54.3 (0.017)[a]	49.4 (0.022)	45.4 (0.027)	47.2 (0.032)[d]	36.6 (0.051)[a,d]	51.2 (0.067)[a]	22.6 (0.065)[a]	32.3 (0.053)	27.2 (0.044)[a]	24.3 (0.035)[a]
Selenium	0.8 (0.005)	0.2 (0.002)	0	0	0	1.2 (0.020)	0	0.4 (0.008)	0	0
Zinc	71.3 (0.025)[a]	60.2 (0.029)[b,a]	51.5 (0.033)[c,a]	33.4 (0.055)[d,a,b,c]	0.7 (0.060)[a,b,c,d]	37.2 (0.080)[a]	10.4 (0.099)[b,a]	14.7 (0.069)[c,a]	2.0 (0.057)[a,b,c]	2.5 (0.029)[a]

[a,b,c,d]Different alphabets denote significantly different between groups, $p<0.05$, by using Multiple Comparison testing with the Bonferroni error correction

Prevalence of inadequacy by wealth quintile

Table 5 presents the prevalence of inadequacy of energy and nutrients by the wealth quintile.

Macronutrients

Inadequacy in protein intake of both underweight and overweight children was significantly higher in the poorest than richest quintile.

As percentage of the total energy, the inadequacy of fat intake was significantly higher in poorest than richest in both underweight and overweight, while that of carbohydrate was significantly lower in poorest than richest.

Vitamins and minerals

For underweight, inadequacies in vitamin A and B12 intake were significantly higher in poorest than the rich quintile; inadequacy in folate was significantly lower in poorest and richest than rich quintile yet intake of the richest was significantly lower than the middle and rich quintiles; inadequacy in thiamine, riboflavin, niacin, vitamin B6 and vitamin C were significantly higher in poorest than richest. For overweight, inadequacies in thiamine, riboflavin, niacin, vitamin B and vitamin C were significantly higher in poorest than the richest quintile. Inadequacies in calcium, iron, phosphorus and zinc intake were significantly higher in poorest than richest.

DISCUSSION

The results of this study have shown the existence of the problem of double burden of malnutrition or the co-existence of underweight and overweight among children in the same age groups, as follows: pre-schoolers (underweight=22%, overweight=4%); younger schoolchildren (underweight=30%, overweight=9%); older schoolchildren (underweight=16%, overweight=10%). This is similar with the results of NNS in 2008 to 2013 wherein a slight decrease in the prevalence of underweight among children under-five (21% to 20%) and 5-10 years (32% to 29%) was observed and the prevalence of overweight in the same age groups at the same periods has shown a substantial increase (3% to 5%; 7% to 9%) (FNRI, 2008; FNRI, 2013).

One way to understand the occurrence of malnutrition among children is to examine their nutrient intake. Adequate amount of nutrients are essential for an overall optimal health status. Excessive intake can lead to obesity and decreased intake to under-nutrition (Population Reference Bureau, 2006). Based on the findings of this study, the energy intake of underweight children was significantly lower than that of overweight children ($p<0.05$) in all age groups. A low and inadequate energy intake was also observed in a study in Indonesia which showed underweight children was far below the recommended allowances and lower than that of normal and overweight children (Syahrul *et al.*, 2016).

The observed higher energy intake of the overweight compared with the underweight children is attributed to the higher percentage contribution fats to the total energy although it was still below the AMDR of 15-30% (FNRI, 2015). The dietary guidelines from the World Health Organization and the Dietary Reference Intakes recommend a total fat intake which is 20-35% of the total calories (IOM, 2000). While fat is needed for the growth and development of children, the quality of fats that should be consumed must be emphasized (Milner & Allison, 1999). The higher consumption of SFA of overweight children in our study is a cause of concern because it is a risk factor for cardiovascular diseases (Te Morenga & Montez, 2017). In addition, the overweight children in our study had almost twice the intake of total sugars and sodium, compared with underweight children. This pattern appears to indicate that the consumption of energy-dense foods might, in turn, result in a reduced consumption of nutrient-dense foods. (Tzioumis & Adair, 2014). The exposure of children to energy-dense, nutrient-poor foods contributes to weight gain and micronutrient deficiencies (Markovic & Natoli, 2009).

This study has also shown that children belonging to the rich quintiles and who live in urban areas, consume more SFA than those who belong to the poor quantiles and those who live in rural areas. However, in developed countries, an inverse relationship between household income and overweight children was found (Wang & Lim, 2012). It could be that in developed countries, high-income families tend to purchase healthy and quality food, have time for exercise and other physical activities, and have better access to health care, whereas higher-income households in developing countries buy cheaper energy-dense and nutrient-poor foods that are beyond their needs (Caballero, 2005). Furthermore, a study on overweight children in China showed that the proportion of energy from fat and animal food sources rose with increasing urbanization and household income levels (Zhang *et al.*, 2017). This is similar to a previous study of Filipino schoolchildren in an urban private school which showed higher proportions of overnutrition than undernutrition, since generally children from private schools have higher socio-economic status (Florentino *et al.*, 2002).

The Filipino diet, which is typically high in carbohydrates with large amounts of rice as staple food but low in animal fat, animal protein and fruits and vegetables, carries the risk for micronutrient deficiencies (FNRI, 2013). Our results show that nutrient inadequacies were seen in both underweight and overweight children of all age groups regardless of their mean usual intake. Key nutrients essential for growth and development of children such as thiamine, riboflavin, vitamin A, vitamin C and zinc were below EAR for underweight children while calcium, iron and folate were below EAR for both overweight and underweight. The 2013 NNS revealed that the prevalence of vitamin A deficiency among children aged 1-5 and 6-12 years was 19.6% and 10.7%, respectively and anemia in the same age groups was 11.2% and 11.1%, respectively (FNRI, 2013). The prevalence of nutrient inadequacy increases with age (Caballero, 2005). This may be due to dietary practices of younger children as this age group is more dependent on parental control. Parents may be more likely to encourage younger children to eat more to gain weight and height (Tang *et al.*, 2010). Several studies have also shown that a lower dietary adequacy is seen in children with mothers of low educational levels, working mothers with high-ranked occupation and those with poor nutritional knowledge and food related health attitudes (Al-Shookri *et al.*, 2011).

Childhood is a crucial period of physical and cognitive development (Tzioumis & Adair, 2014). Nutrition programmes aimed at improving dietary behaviour should target both underweight and overweight children from all socio-economic strata and geographical locations since they are all at a great risk for developing micronutrient deficiencies. Undernutrition hinders children's potential for growth. It also contributes to cognitive impairment, resulting in delayed school entry, poor school performance and lower graduation rates (Victora *et al.*, 2008). Childhood obesity on the other hand may eventually lead to the occurrence of hypertension, type 2 diabetes mellitus and other non-communicable diseases in adulthood (Goran, Ball & Cruz, 2003).

This study has provided a comprehensive summary of the differences in the dietary intakes of underweight and overweight Filipino children. The use of mean intakes provided a general overview of nutrient intake levels of the population, while the EAR cut-point method with the national representative sample allowed an estimate of the prevalence of the population with inadequacy intakes. A detailed segmentation of the studied sample by age group, location of residence (i.e. urban or rural) and wealth quintile is essential to ensure tailored nutritional solutions to meet the needs of specific subgroups of the population.

Our study also had several limitations. Firstly, the use of 24-hour recalls to collect dietary intake data relies on the ability of the participants to accurately recall the foods and sizes of the portions that they consumed. Secondly, information on use of dietary supplements was not captured in this study, which could under-estimate the nutrient intakes. Thirdly, the construction of the Filipino FCT involved matching similar food items with established databases such as that of the United States Department of Agriculture (USDA). In reality, however, the nutritional content could be different for similar foods, due to different breed cultivars, climate conditions, mineral abundance in soil and national food fortification policies. Therefore, the findings reported in this study could be subject to measurement errors. If possible, these dietary intake data should be looked at in relation to nutritional biomarkers and health conditions to facilitate better interpretation.

CONCLUSION

Our result highlights evident findings that under- and overweight coexists within the same age groups of children together with nutrient inadequacies. The percentage of fat contribution to energy intake was higher among the overweight than the underweight. It also indicates that important disparities in socioeconomic status and locality may affect the nutrient intake of children. Clearly, underweight Filipino children belonging to the rural and poorest sectors have inadequate nutrient intake. The same scenario was also seen among overweight children from the urban and richest quintiles. Further research is needed on risk factors that affect nutrient adequacy or inadequacy in both spectrum of nutritional status in different age groups, environmental and socio-cultural settings. Targeted, specific and sensitive nutritional interventions should be implemented and enhanced to control the occurrence of double burden of malnutrition in the country.

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Authors' contributions

IAA, the project leader in the 2013 NSS, conceptualised and designed the manuscript; PIGA, drafted and reviewed the manuscript; WPL, performed statistical analysis and data interpretation.

Conflict of interest

The authors declare no conflict of interest in the publication of this article.

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