VOLUME 35 ISSUE 5
OCTOBER 2022

JHND

Journal of Human Nutrition and Dietetics

EDITOR: Simon Langley-Evans

WILEY

THE OFFICIAL JOURNAL OF THE BRITISH DIETETIC ASSOCIATION

BDA The Association of UK Dietitians

Journal of Human Nutrition and Dietetics

The Official Journal of the British Dietetic Association

Aims and editorial policy

Journal of Human Nutrition and Dietetics is an international peer reviewed journal publishing papers in applied nutrition and dietetics. Papers are therefore welcomed on:

- Clinical nutrition and the practice of therapeutic dietetics
- Public health nutrition and nutritional epidemiology
- Health promotion and intervention studies and their effectiveness
- Food choice and the psychology of eating behaviour
- Food intake and nutritional status
- Sociology of food intake

Further information on this journal can be accessed at wileyonlinelibrary.com/journal/jhn

The *Journal of Human Nutrition and Dietetics* is published by Blackwell Publishing Ltd: 9600 Garsington Road, Oxford OX4 2DQ, UK. Tel: +44 1865 776868; Fax: +44 (0)1865 714591. Blackwell Publishing was acquired by John Wiley & Sons in February 2007. Blackwell's programme has been merged with Wiley's global Scientific, Technical and Medical business to form Wiley Blackwell.

Production Editor: Divya Pundir (email: jhn@wiley.com)

Journal of Human Nutrition and Dietetics

Volume 35 • Issue 5 • October 2022

Received: 31 January 2022 | Accepted: 6 April 2022

DOI: 10.1111/jhn.13023

JHND Journal of Human Nutrition and Dietetics | BDA The Association of UK Dietitians

Early life programming of health and disease: The long-term consequences of obesity in pregnancy

Simon C. Langley-Evans

School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough, UK

Correspondence

Simon C. Langley-Evans, School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough LE12 5RD, UK.
Email: Simon.langley-evans@nottingham.ac.uk

Abstract

The prevalence of overweight and obesity is rising in all parts of the world and, among young women, it presents a very clear danger during pregnancy. Women who are overweight or who gain excessive weight during pregnancy are at greater risk of complications in pregnancy and labour, and are more likely to lose their child to stillbirth or die themselves during pregnancy. This narrative review considers the evidence that, in addition to increasing risk of poor pregnancy outcomes, obesity has the capacity to programme foetuses to be at greater risk of cardiometabolic disorders later in life. An extensive body of evidence from prospective and retrospective cohorts, as well as record linkage studies, demonstrates associations of maternal obesity and/or gestational diabetes with cardiovascular disease, as well as type 1 and type 2 diabetes. Studies in animals suggest that these associations are underpinned by adaptations that occur in foetal life, which remodel the structures of major organs, including the brain, kidney and pancreas.

KEYWORDS

cardiovascular disease, diabetes, disease, life phase, obesity, pregnancy, therapeutic areas

Highlights

- Foetal exposure to maternal obesity is associated with greater risk of childhood obesity, cardiovascular disease, type 1 and type 2 diabetes, and renal disease.
- Animal studies suggest that the programming of health and disease by maternal obesity is likely to be underpinned by remodelling of organ structures during development.
- Placental adaptations to maternal obesity, including inflammatory responses, may mediate the foetal tissue remodelling that occurs in response to maternal obesity or excessive antenatal weight gain.
- Transgenerational cycles of obesity and related disorders, with transmission through the maternal environment during pregnancy, make intervention a high public health priority. In addition to the periconceptual period, there are windows of opportunity around breastfeeding and the timely and appropriate introduction of complementary foods in infancy.

THE LONG-TERM CONSEQUENCES OF OBESITY IN PREGNANCY

The determinants of health and disease

The last 30–40 years have seen a profound change in our understanding of relationships between lifestyle and chronic disease. Recognition that lifestyle factors could modulate risk of non-communicable disease arose from the seminal works by Doll and Peto[1] on tobacco smoking and cancer and the elucidation of relationships between dietary fat, cholesterol concentrations and the contribution of low-density lipoprotein-cholesterol to atherosclerosis.[2,3] Following on from this recognition came the now well-established view that risk is heavily determined by the interaction of lifestyle factors and the genotype. The phrase 'genes load the gun but the environment pulls the trigger' is widely quoted,[4] after having been coined by Judith Stern, a nutritionist from the University of California. The research that is described in the present review adds another layer to our understanding of the lifestyle–disease relationship and, as will be discussed, it is perhaps more accurate to say that genes load the gun, early life factors take aim and the environment pulls the trigger.

Figure 1 shows how different elements of broad human biology establish risk of disease at any stage of life. The contribution of genetics is strongest in the earlier years and a high proportion of non-communicable disease in infants and children will have a strong genetic component. The influence of lifestyle (smoking, diet, alcohol, socioeconomic status, occupational exposures and behaviours) becomes stronger as we age, but will always be modified by the underlying genotype. However, the phenotype also plays a critical role. 'Genotype' describes the information encoded by DNA, whereas 'phenotype' refers to the traits the individual has when the genotype is expressed. The translation of the genotype to phenotype will be modified by epigenetic factors (tags on DNA and histone proteins that modulate gene expression in response to a range of factors, including the environment) and the environment encountered during foetal and infant development. It is helpful to regard health and disease status at any stage of life as being the product of cumulative gene–environment interactions at all previous stages of life.[5] The outcomes of such interactions at one stage of life will establish the phenotypic traits that determine how future interactions progress. This could be regarded as a lifecourse approach to understanding disease, or to stretch Stern's gun analogy further, we might say that the aiming of the weapon prior to the environmental trigger that causes detriment becomes more focused with ageing.

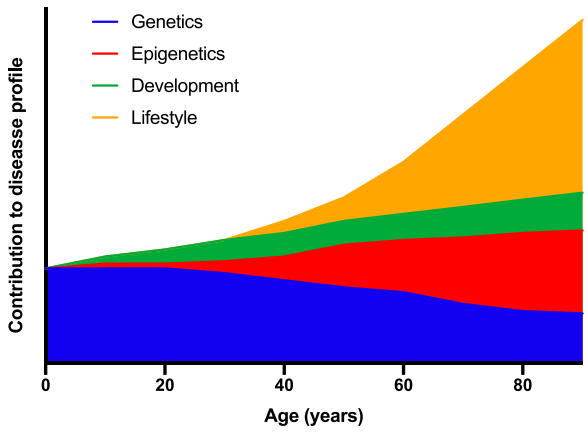

FIGURE 1 The underlying determinants of health and disease are complex and vary across the lifespan. At all stages of life, health status is a product of gene–environment interactions. In early life, genetics plays a more important role than in later life. Risk of disease at all stages of life is a product of the outcomes of gene–environment interactions at earlier stages

Because early development, particularly during the phase of life when organogenesis irreversibly establishes tissue structures, is a contributing factor to disease risk many decades later, exploring the relationship between maternal nutritional status in pregnancy and infant development is of great interest. Although there is an extensive body of evidence considering how maternal undernutrition can 'programme' later disease,[6] the major nutritional concern in contemporary society relates to overweight and obesity. Figure 2 shows recent trends in overweight and obesity for adult women and infants aged 2–4 years. The marked rise in prevalence in both groups is striking, and the impact of widespread overweight among women of childbearing age upon the health of future generations is yet to be fully evaluated. The aim of this review is to discuss the evidence that links early life events to disease in later life and consider observations that indicate that maternal obesity is a key driver of non-communicable disease in the next generation. In the review the focus will be primarily on epidemiological associations between early life and later disease, although findings from experimental animal studies will be described as a means of illustrating the mechanisms the likely mechanistic links.

MATERNAL OBESITY AND PREGNANCY OUTCOMES

The risks associated with obesity in pregnancy manifest during the pregnancy itself, although this review focuses on the later impacts on the health of individuals who experienced maternal obesity during foetal development. Maternal weight status is an important determinant of pregnancy outcomes for both mothers and babies, and also of obstetric complications.[8] Overweight, obesity and excessive gestational weight gain are all risk factors for poor outcomes. Optimal gestational weight gain is dependent on weight status going into pregnancy.

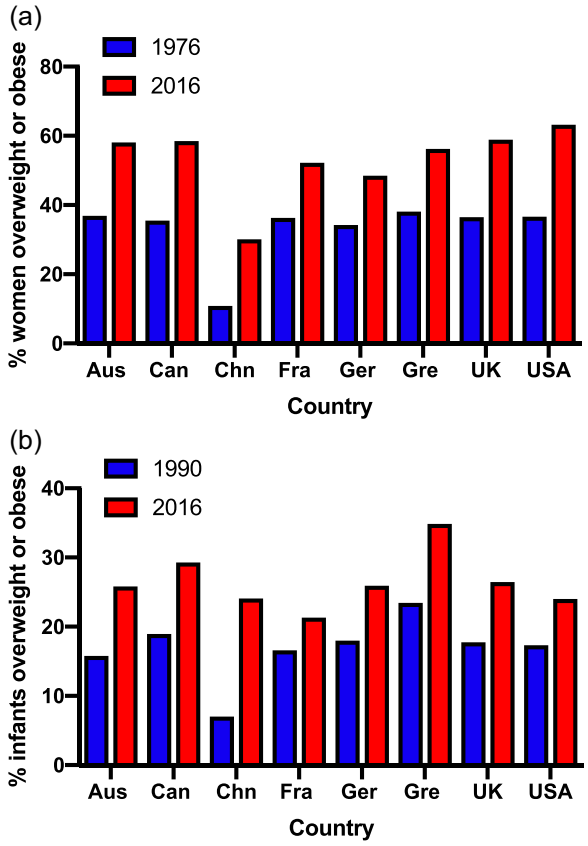

FIGURE 2 The rising prevalence of obesity. (a) Overweight and obesity among adult women in selected countries. (b) Overweight and obesity among children aged 2–4 years in selected countries. Data from Ritchie and Roser.[7] Aus, Australia; Can, Canada; Chn, China; Fra, France; Ger, Germany; Gre, Greece; UK, United Kingdom; USA, United States of America

Although women of ideal weight prepregnancy may gain up to 16 kg across pregnancy, for those who are obese, a gain over 9 kg would be considered excessive.[9]

Obesity and excessive weight gain increase the risk of miscarriage[10] and stillbirth.[11] Obesity also increases risk of maternal death by up to two-fold, relative to ideal weight women, depending on the severity of the obesity.[12] Overweight, obesity and excessive weight gain increase risk of all obstetric complications ranging from relatively minor gastrointestinal disturbances[13] through to the more severe hypertensive disorders[14] and gestational diabetes (GDM)[15]. It is estimated that obesity increases the risk of pre-eclampsia by between 2- and 2.5-fold[16] and, because the clinical response to this condition is to deliver the baby early, obesity becomes a key risk factor for preterm delivery. The association between obesity and gestational diabetes increases risk of macrosomia and injury to infants during delivery.[17] Obesity and excessive gestational weight gain also increase the risk of complications in labour. Spontaneous initiation of sustained labour is impaired, making induction more common in women with a body mass index (BMI) > 30 kg m^{-2}.[18] Interventions, including instrumented delivery and caesarean section, are more frequent in pregnancies complicated by maternal obesity.[19,20]

THE EARLY LIFE ORIGINS OF HEALTH AND DISEASE

The starting point for this review was the idea that lifelong risk of non-communicable disease is a product of interactions between genetic and epigenetic factors with the environment at all stages of life. Disease risk at any given point in life is partly determined by prior (epi) genetic–environment interactions. The impact of such interactions during foetal development is particularly significant and exposures to adverse environments during this phase of life are said to programme later disease risk. In this context 'programming' refers to permanent, irreversible adaptations to the environment, which compromise capacity to maintain normal metabolic and physiological function with ageing.[6]

The embryos of all animal species begin development with the potential to develop and grow at a rate and to a form, that is determined by the genotype inherited from both parents. The expression of that genetic potential will lead to an achieved phenotype (Figure 3), which includes all aspects of anatomy, physiology, metabolism and endocrine functions, and hence the balance between health and disease. The early life programming concept is based on the contribution of modifying factors that alter the expression of the genotype and hence the achieved phenotype. Modifying influences on development will change the achieved phenotype at the level of individual organs, systems, tissues and even specific cell types by altering rates of cell division and differentiation. These changes will determine the number of cells and types of cells within a tissue and hence its resilience and homeostatic responses to physiological and metabolic challenges from the environment (dietary surplus or deficit, infection, trauma).[6] Ultimately, the establishment of the phenotype from the genotype is never complete and it continues to change throughout life, although tissues are at their most plastic during the phases of organogenesis and maturation which, in humans, occur before birth. In this way, exposure to environmental factors establishes the functional lifespan of each organ, meaning the length of time over which it can maintain normal function and the capacity to withstand further adverse conditions. Beyond this functional lifespan, each tissue will decline in function and disease will develop.

The range of factors known to have a programming effect on the developing foetus is known to be broad (Figure 3). Inevitably, most factors are maternally derived as the intrauterine environment is where the foetal genotype encounters stimuli from the outside world, but there is an emerging body of evidence that suggests paternal factors carried by semen may also have

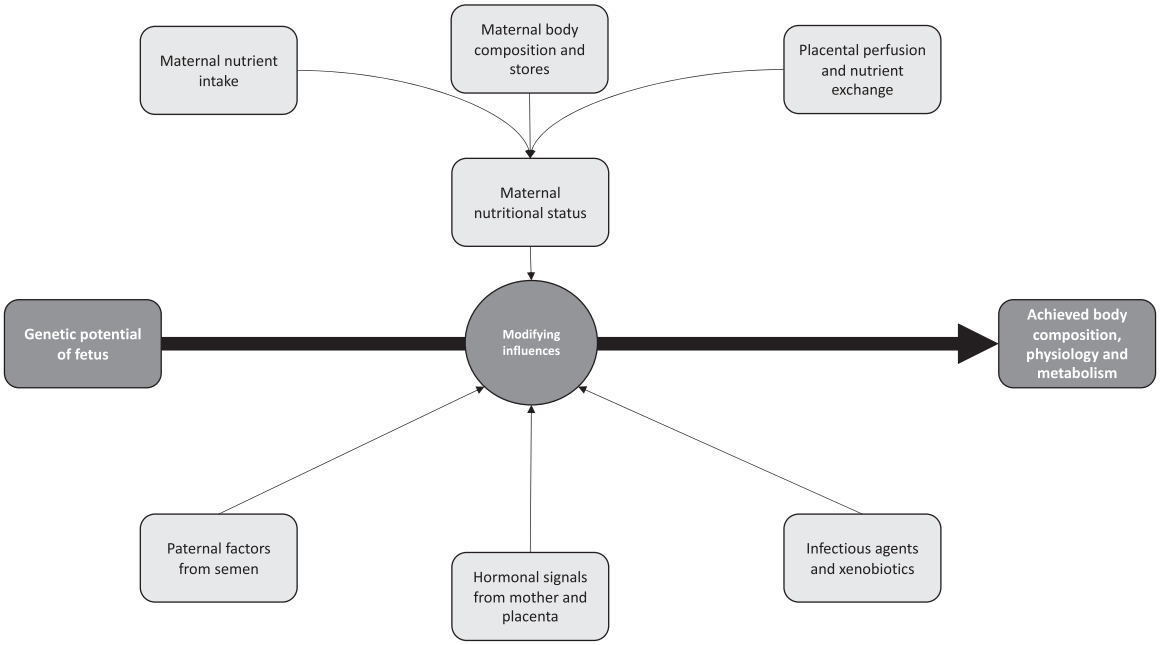

FIGURE 3 Maternal and paternal factors modify genetically determined developmental potential to determine the foetal genotype at birth

programming potential. Most attention has focused on the influence of maternal nutritional status, and in particular undernutrition. The way in which that is signalled to the embryo and foetus is complex and nutritional status is, in itself, a product of maternal intakes, nutrient demands and stores.

The first compelling evidence that early life events could programme disease in adulthood was derived from ecological and retrospective cohort studies. Comparing the geographical distributions of place of birth and cause of death among more than 2 million individuals who died in England and Wales suggested a strong influence of the former upon risk of coronary heart disease in the 1970s.[21] Similarly, the distribution of death from coronary heart disease mapped closed onto the distribution of infant death in the 1920s.[22] This suggested that deprivation in early life was related to subsequent disease and cause of death and that this relationship persisted even when people moved to more affluent parts of the country. Further studies found strong associations between anthropometry at birth and risk of disease in adult life. Across cohorts in many countries, including the UK, Sweden, USA and India, it was noted that lower weight at birth (but still within the normal range) was associated with higher risk of blood pressure in adulthood, type 2 diabetes, insulin resistance and death from coronary heart disease.[23–28] These observations were particularly robust for type 2 diabetes and meta-analysis suggested a 25% greater risk of adult diabetes with every 1 kg lower weight at birth.[29]

Other indices of infant anthropometry at birth were also found to be associated with risk of ill-health in childhood and adult life. A larger head circumference, for example, was associated with greater risk of atopic wheezing in primary school age children.[30] Thinness at birth, measured as the ponderal index (weight/length^3), was found to associate with risk of type 2 diabetes as an adult,[31] and a smaller abdominal circumference was associated with cardiovascular disease.[32] Collectively, these observations led to the theory that factors that constitute an adverse environment for foetal development, result in irreversible changes to how organs and tissues develop, effectively programming their lifelong function and risk of non-communicable disease for the exposed individual. The extremes of anthropometric indices at birth are the immediate indicator that the maternal environment has constrained genetic potential for growth. In keeping with the idea that risk of disease at any stage of life is the product of cumulative exposures to adverse factors at earlier stages, more complex analyses of retrospective cohorts showed interactions between foetal and adult factors. Risk of insulin resistance in 50-year-old men and women was greatest in those who were born thin (low ponderal index) but had higher body mass index as adults.[33] Finnish women born in the 1920s and 1930s were more likely to develop coronary heart disease if they were of low birthweight and gained weight more rapidly up to the age of 9 years.[34] Similarly, the interaction of early life factors with the genotype is evident from observational data. Associations between common single nucleotide polymorphisms (gene variants) and disease were only manifested in individuals of lower birthweight in a cohort of Finnish adults.[35,36]

The originators of the programming hypothesis postulated that the principle driver of early life

programming was maternal undernutrition because evidence suggested that birth anthropometry was determined by maternal nutritional status and because, at the time the participants in the retrospective cohorts were conceived and born (early 20th Century), undernutrition was considerably more common than overnutrition, overweight and obesity. Reinforcement of the nutritional programming hypothesis came from follow-up studies of individuals conceived or born during the Dutch Famine of 1944–1945. At the end of World War II, Nazi blockade of food supplies to western Holland resulted in 6 months of famine conditions. Adults who were conceived at this time were more likely to develop obesity, type 2 diabetes and coronary heart disease than those born just before or just after the famine.[37,38] Undernutrition at different stages of foetal development had differential effects on disease in adult life. Exposure to famine in early gestation was associated with greater risk of coronary heart disease, schizophrenia and depression, whereas exposure at any stage of gestation was associated with type 2 diabetes.[37] Similarly, foetal exposure to the Great Chinese Famine of the 1950s was associated with greater risk of ischemic heart disease and stroke, non-alcoholic fatty liver disease and type 2 diabetes[39–41] but not left atrial enlargement.[42]

There are different ways of viewing the relationship between anthropometry at birth and disease in adult life. Nobody would view being born small as being a direct cause of non-communicable disease. Lower weight or thinness at birth are merely indicators of risk. There are three main schools of thought about what the observed relationship means. The simplest view is that the association represents a trade-off in foetal life. Adverse conditions in pregnancy as a result of undernutrition or other maternal stressors either result in death of the embryo or foetus, or the conceptus survives through adaptations of tissue structures.[6] These adaptations become permanent as they occur during organogenesis, and are subsequently disadvantageous to the adult (Figure 4). Others have considered the persistence of what appears to be maladaptation through evolution and have proposed that, when the foetus adapts to the prevailing environment encountered by its mother, it develops characteristics preparing it for the continuation of that environment after birth. Disease risk will only develop if conditions improve.[43,44] For example, conditions of undernutrition would be better responded to if an individual were programmed in foetal life to be more energetically efficient. However, if in future the individual lives in an environment where nutrition is plentiful, then they would be more likely to become obese. The third viewpoint is that the birth anthropometry–later disease association is an indication that there are genetic variants that mediate both foetal growth restriction and non-communicable disease.[45] For example, Warrington *et al.*[46] reported on genome wide association analysis of maternal and offspring genotypes, birthweight and cardiometabolic disease in a population of more than 200,000 individuals. The analysis found 190 independent association signals indicating that the foetal genotype determined both birthweight and adult blood pressure. This would discount any involvement of maternal nutritional status or other putative programming factors.

The foetal programming hypothesis is also open to criticism because so much of the supporting evidence is dependent upon retrospective analysis of data gathered for other purposes. Studies that attempt to link indicators of the foetal environment with outcomes that manifest more than five decades later are inevitably vulnerable to confounding factors that cannot be fully controlled for in the statistical analysis.[6,47] In most studies, except those that have involved follow-up of the wartime and other famines, there is no direct measure of maternal nutritional status and much is inferred from birth anthropometry as an imperfect proxy of undernutrition. A number of prospective cohort studies[48–50] have been established to investigate the maternal nutrition relationship with offspring health, but all of these are still many decades away from yielding useful observations that can adequately confirm or refute the hypothesis.

Given the counter-arguments to the nutritional programming hypothesis, it has been important to assess the biological plausibility of the concept using

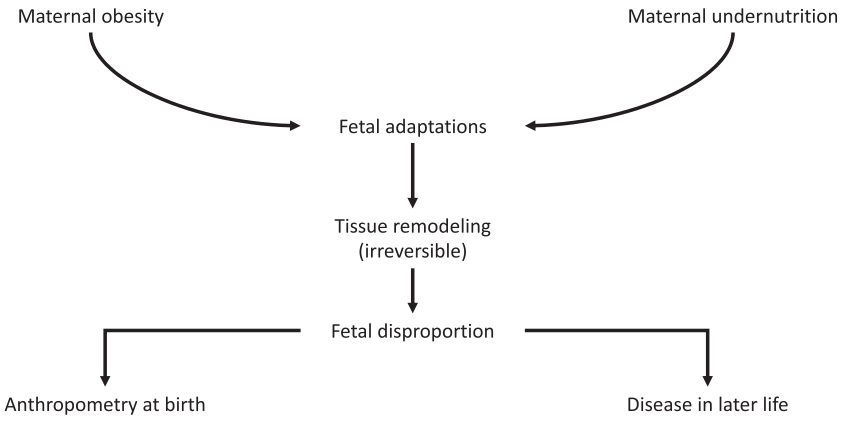

FIGURE 4 Programming of disease in later life can be driven by both maternal under- and overnutrition

experimental animal models. These have been able to demonstrate direct programming responses to manipulation of maternal diet, in the absence of genetic variation. Tests of the maternal diet–disease relationship have shown that the concept holds true, with a high degree of confidence. Programming through maternal undernutrition has been shown in a wide range of mammalian species including pigs, sheep, guinea pigs, mice and rats.[47] In genetically in-bred rodents, restriction of maternal food intake, induction of iron deficiency and feeding a low protein diet in pregnancy impair foetal growth, disrupt placentation, lead to defects of glucose homeostasis, increase blood pressure and impair renal function in adult offspring, whose lifespans are reduced.[51] Studies of non-human primates also demonstrate that maternal undernutrition in pregnancy adversely programmes physiological and metabolic function in the exposed offspring.[52] Critically, the animal studies have shown that maternal undernutrition can programme later disease without any effect on birthweight. This undermines the argument that epidemiological evidence of programming is explained by genetic variants that influence both foetal growth and long-term cardiometabolic functions.[45]

As in humans, the adverse effects of maternal undernutrition upon offspring tend to develop with ageing. For example, rats exposed to low protein diets during foetal life can maintain normal renal function until they are 9 months old (approximately 40% of lifespan) but thereafter function declines more rapidly than in control rats and many males subject to maternal protein restriction die as a result of renal failure.[53,54] The same animals exhibit enhanced homeostatic responses to glucose loads as young adults but, at 18 months old, are insulin resistant, whereas control animals rarely show this impairment.[55,56]. Consistent with the lifecourse view of health and disease, responses to nutritional challenges in adult life are modified by the foetal nutritional experience. Rats whose mothers were severely food restricted in pregnancy have an exaggerated response to a hypercaloric diet as adults, becoming more obese and metabolically impaired than offspring of mothers who were fed their normal diet.[57] Genetically modified mice with a diet-dependent predisposition to coronary heart disease had a greater atherogenic response to a high cholesterol diet if exposed to maternal protein restriction *in utero*.[58]

MATERNAL OBESITY AND THE PROGRAMMING OF DISEASE

With respect to investigating the associations between maternal undernutrition and programming of disease, experimental animal studies proved to be a useful follow-up to the epidemiological observations, critically demonstrating the biological plausibility of the programming hypothesis and generating data relating to possible programming mechanisms. When considering possible links between exposure to maternal obesity and disease in adult life, the animal studies came largely before any amassing of compelling epidemiological evidence.

Obesity can be difficult to induce in experimental animal species as rodents, in particular, are better able than humans to regulate their energy balance.[59] Rats and mice are the species of choice for experimental models, and many studies rely on feeding diets high in fat and sugar to increase adiposity. Studies of this nature have shown that obesity in pregnancy can programme glucose intolerance, dyslipidaemia and elevated blood pressure in offspring.[60] However, these experiments may be confounded by the fact that the offspring are exposed directly to these diets in addition to the maternal adiposity during foetal development and the suckling period. To modify the maternal diets to increase fat and sugar content inevitably reduces intake of protein and micronutrients and this is known to have a programming impact in itself.[47] It is important to appreciate that these diets are provided to animals as a homogenous, pelleted foodstuff and ingesting high quantities of sucrose or specific fatty acids may be directly responsible for programming effects through their bioactivity, rather than the interpretation that the effects are a result of maternal obesity.[59]

An alternative approach has been to induce obesity using cafeteria feeding. This involves rats being offered a constantly changing array of highly palatable human foods in addition to their baseline (low energy) rodent feed.[59,61–64] Once obesity is established, the rats can be transferred to their lower energy food, or maintained on the cafeteria diet for pregnancy, and offspring can be kept with their mothers or cross-fostered to mothers with a different dietary or weight status. In this way, the effects of obesity during pregnancy and lactation can be studied independently of direct dietary effects. This approach has shown that maternal obesity can programme brain development and behaviour, adiposity and glucose homeostasis in offspring.[63–66] Rats exposed to cafeteria diet *in utero* have an enhanced preference for high sugar and high fat foods when they are adults. In non-human primates, maternal obesity has similar effects to that observed in rodents. In young Japanese macaques, the offspring of obese mothers fed a Western style diet exhibited impaired insulin sensitivity in muscle even before they were weaned.[67] Hypersecretion of insulin by pancreatic islets of young macaques exposed to this Western diet *in utero* suggests that there is a programmed dysfunction of glucose metabolism that will deteriorate with ageing.[68]

In humans, it is well recognised that there is a strong genetic component to obesity. Individuals with one or two obese parents are more likely to be obese themselves and the heritability of an obese phenotype has been estimated to be as high as 70%. Whitaker *et al*.[69] reported

that the risk of obesity with one obese parent was doubled, but interestingly the relationship was stronger where it was the mother who was obese. Such observations do not only reflect genetic influences because children will generally share their environment with their parents and hence experience the same dietary and behavioural drivers of excessive fat deposition. Exploration of a possible programming basis for this was initially stuck on the idea that low birthweight was a driver of later disease, as discussed earlier in this review. Studies showed that birth anthropometry was predictive of later obesity. A longitudinal follow-up of the 1956 UK Birth Cohort found a J-shaped relationship between birthweight and BMI in 33-year-old men and this appeared to be heavily driven by maternal but not paternal weight.[70] A Finnish study found that the risk of abdominal obesity was greater in young adults who had been born small-for-gestational age.[71] Generally, the evidence supported the view that obesity in adolescence and adulthood was predicted either by low birth weight or being a large baby at birth.[72] These observations of indirect relationships between early life exposures, with birthweight as a proxy are, however, somewhat obsolete given there are more recent reports of direct associations between maternal BMI and adverse health indicators and outcomes in offspring.

The Growing Up Today study has followed up approximately 15,000 children of women who participated in the well-characterised US Nurses Health Study.[73] When followed up in adolescence, those who had been exposed to GDM during foetal development were more likely to be overweight. The analysis indicated an independent influence of maternal BMI in this relationship.[73] If mothers maintained a healthy weight before pregnancy and engaged in a healthy dietary pattern, 150 min or more of moderate/vigorous exercise and avoided smoking, then their children were less likely to be obese between 9 and 14 years.[74] Maternal BMI between 18.5 and 24.9 kg m^{-2} was associated with a lower risk of childhood obesity (odds ratio [OR] = 0.44, 95% confidence interval [CI] = 0.39–0.50 relative to higher BMI range) and maternal BMI was the strongest predictor of childhood weight outcomes. Other studies have similarly indicated that adiposity is greater in children whose mothers were living with obesity.[75–77] A follow-up of Thai 19–22 year olds found a 25% greater risk of obesity for every 1 kg m^{-2} increase in maternal BMI. The risk of offspring obesity among the children of mothers with BMI in the obese range was 17-fold higher than in children of mothers of ideal weight.[78]

Of far greater significance are the observations that maternal obesity has a long-term impact on metabolic function and disease outcomes. Some of these have been derived from record linkage studies of very large populations. Follow-up of 2.23 million Swedish births between 1992 and 2016 found that diagnosis of cardiovascular disease between the ages of 1 and 25 years was more likely in those whose mothers had been obese in pregnancy than it was in those whose mothers had been of ideal weight.[79] The risk was graded so that, although those whose mothers had BMI between 30 and 34.9 kg m^{-2} were 16% more likely to have cardiovascular disease, this increased to 2.51-fold if maternal BMI was over 40 kg m^{-2}. Tan *et al.*[77] found that elevated cardiovascular disease risk factors (raised blood pressure, dyslipidaemia) were present in 13-year-old children of mothers who were overweight or obese relative to children of mothers of ideal weight. Follow-up of Finnish men and women born between 1934 and 1944 found that those whose mothers had had a BMI > 28 kg m^{-2} in pregnancy were at greater risk of cardiovascular disease. Men were more prone to coronary heart disease and women to stroke.[80] Reynolds *et al.*[81] showed that, among 37,709 34–61-year-olds, all-cause mortality was greater in those whose mothers had been obese than in those whose mothers had been of idea weight. Offspring of mothers with BMI > 30 kg m^{-2} were also more likely to have had a hospital admission with cardiovascular disease (OR = 1.29, 95% CI = 1.06–1.57).

Exposure to maternal obesity is associated with metabolic dysfunction. Boney *et al.*[82] reported that 11-year-old children were at increased risk of developing the metabolic syndrome if born to mothers living with obesity. A similarly elevated risk of insulin resistance was observable in young men and, to a lesser extent, women if their mothers were obese,[76] whereas Bucci *et al.*[83] reported muscular insulin sensitivity was impaired in frail elderly men (average age 72 years) whose mothers had been obese. Follow-up of men and women born in Helsinki in the 1930s and 40 s demonstrated that women whose mothers were of higher BMI were at greater risk of developing type 2 diabetes as adults.[80] In the same way, record linkage of 118,201 Aberdeen births (1950–2011) to the Scottish diabetes register revealed that offspring of overweight (OR = 1.39, 95% CI = 1.06–1.83) and obese (OR = 3.8, 95% CI = 2.33–5.06) mothers were at markedly elevated risk of type 2 diabetes.[84] There is also evidence that maternal obesity increases the risk of type 1 diabetes as among more than 1.26 million Swedish children born between 1992 and 2004, obesity in pregnancy predicted a type 1 diabetes diagnosis (OR = 1.33, 95% CI = 1.2–1.48).[85] Similarly, analysis of data relating to the births of children who were subsequently hospitalised with type-1 diabetes found that maternal BMI > 30 kg m^{-2} was a significant risk factor (OR = 1.29, 95% CI = 1.01–1.64).[86] To some extent, this relationship could be explained by the association of maternal obesity with higher birthweight because there is an association between higher weight at birth and type 1 diabetes.[87] Alternatively, it may be that maternal obesity is a driver of autoimmune damage to the infant pancreas. Analysis of blood markers of islet autoimmunity in neonates found that maternal obesity and gestational weight gain over 15 kg were associated

with an autoimmune profile,[88] although other studies have not confirmed this observation.[89] Further studies suggest that maternal obesity may programme renal development and function[90] and asthma.[91]

A number of studies are suggestive of programming effects of maternal obesity and/or obesogenic diets on appetite and food preferences in humans. A preference for a higher carbohydrate intake was observed in adult men, whose mothers were obese in pregnancy.[92] Follow-ups of the Avon Longitudinal Study of Parents and Children found that, at age 10 years, dietary choices were strongly related to those of mothers prepregnancy. There was no evidence of any paternal influence on children's food choice, and the relationship between childhood feeding and mother's postnatal behaviours was less marked. This supports the idea that appetite regulation is programmed *in utero*.[93] In the same cohort, unhealthy maternal behaviours including consumption of 'junk' food in pregnancy was associated with fat mass in 15-year-old children, again with no paternal influence.[94] Wardle *et al.*[95] found that, among lean children with overweight or obese parents, there was a higher preference for fatty foods in taste tests and an 'over-eating' eating style. Although the study did not split the cohort dependent on whether the mothers or fathers were obese, the average BMI of the mothers in the study was 36 kg m^{-2}, whereas it was only 29 kg m^{-2} for the fathers. The data add to the view that maternal obesity determines offspring feeding behaviour in humans, as it does in experimental animals.[66,96,97]

MECHANISTIC PERSPECTIVES ON PROGRAMMING BY OBESITY

Many putative mechanisms have been suggested to explain how maternal nutritional status during pregnancy can programme disease risk in the exposed offspring. For any programming to take place, there needs to be some signal, or signals, of the maternal environment to the foetus. This signal then has to be recognised and elicit a response. There is a lot of debate about the process of recognition to initiate the response, with many researchers suggesting that maternal nutritional status elicits changes to the foetal epigenome and thereby sets in train long-term physiological adaptations, although the evidence for this is, as yet, not wholly convincing. The nature of the response to the maternal environment is somewhat easier to determine and one of the simplest mechanisms that can explain how variation in maternal nutritional status (including obesity) brings about changes in foetal anatomy and physiology involves the process of tissue remodelling. This rests on the idea that changes to the numbers of cells or the type of cells present within a tissue will reshape the morphology of that tissue and could have profound effects upon organ function.[6]

All organs and tissues are derived from small populations of embryonic progenitor cell lines, which go through waves of rapid cell proliferation and differentiation to achieve their development before parturition. An adverse maternal environment during these critical periods can effectively prevent formation of an optimal number of specialised structures (i.e. remodelling the genetically determined pattern) and limit the functional capacity of the mature organ. There is extensive evidence from animal studies of maternal undernutrition which demonstrates remodelling takes place in response to adverse conditions in a range of organs, including the kidneys, brain and pancreas[98–100] This remodelling appears to underpin foetal programming of renal disease, appetite regulation and impaired metabolic regulation. Although harder to demonstrate in humans, there is evidence of associations between low birthweight and renal structure.[101–103] The evidence base for tissue remodelling in response to maternal obesity is more limited but, in rodents, there is evidence that offspring of obese mothers fed a cafeteria diet prior to pregnancy also have altered renal structure (lower nephron number; A. Akyol and S. Langley-Evans, unpublished data). Interestingly, ultrasound examination of the kidneys of infants who mothers were obese indigenous Australians indicated that they had lower kidney volume, consistent with having been remodelled.[90]

Modifying the numbers and types of cells present within a tissue will have a range of consequences and the knock-on effects on metabolic and physiological regulation will establish a predisposition for non-communicable disease. This will not manifest as disease in childhood, instead being revealed when the individual undergoes metabolic or physiological challenge, or as tissue functions naturally deteriorate with age. Alterations to the profile of cell types present within a tissue may also modify the capacity of a tissue to produce or respond to hormones, alter gene expression or interfere with cell signaling pathways. Some of these changes may have very localised effects, simply impacting upon the function of a particular tissue, but others could disrupt regulation throughout the body. The epidemiological evidence that points to an association between maternal obesity and later disease in humans is well matched with the evidence from animal studies, and both point to disruption of metabolic regulation at the whole-body level. As shown in Figure 5, this may result from remodelling of multiple tissues. Remodelling of adipose tissue so that there are fewer cells may underpin the observed propensity for offspring of women with high BMI to become obese because adipose tissue dysfunction impacts both the storage capacity of the tissue and regulation of metabolism by adipokines. Insulin resistance and the reported type 1 and type 2 diabetes in individuals exposed to obesity in foetal life could be explained by pancreatic remodelling and programming

of liver structure could contribute to a number of metabolic anomalies including the dyslipidaemia reported by Tan *et al.*[77] Remodelling of the hypothalamus has been reported as an outcome of maternal protein restriction in rats. If the tissue were also sensitive to maternal obesity, then the impact on whole-body homeostasis could be profound. Evidence from rodent studies suggests maternal obesity during lactation does have an impact on hippocampal and hypothalamic neurotransmitter production, with consequent effects on behaviour and feeding.[65,66,104] The observations that men who had obese mothers have a greater preference for carbohydrates[92] and that children's food preferences follow their mother's prepregnancy behaviours but not their father's,[93] may indicate that the same mechanisms could operate in humans.

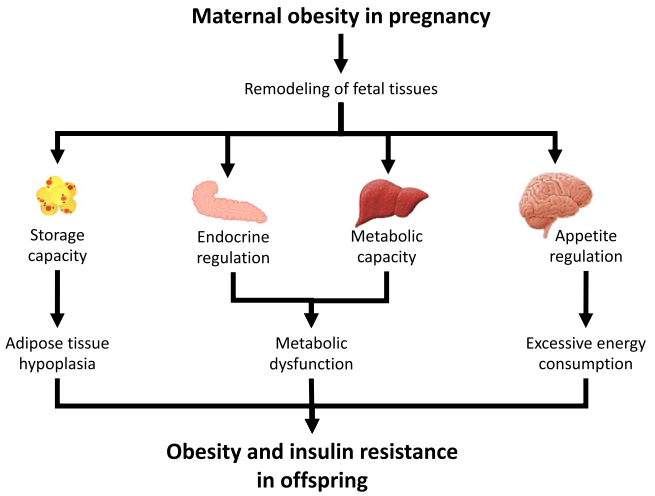

FIGURE 5 Remodelling of the structures of specific tissues in foetal life may explain how maternal obesity programmes offspring adiposity and metabolic function

Tissue remodelling provides a route through which the adverse developmental environment of maternal obesity can programme offspring health, but does not explain how the foetal tissues receive signals of that environment. Whatever the programming stimulus or insult is, there is little doubt that it is mediated via the placenta. As shown in Figure 6, the placenta is not a passive facilitator of movement of oxygen, substrates and metabolic waste products between maternal and foetal compartments. It is a metabolically active tissue that generates substrates for the foetus and is a source of hormones and growth factors. All signals between mother and foetus are subject to modulation by placental activity.

The impact of maternal obesity on placentation is demonstrated by the greater risk of pre-eclampsia[104] in obese women. In pre-eclampsia, inflammatory processes and oxidative injury leads to arterial dysfunction and breakdown of transport capacity.[105] It is likely that the condition is the extreme endpoint of damaging impacts of maternal obesity on placental integrity and function. This probably has adverse programming effects on foetal development. Histopathological analyses of placentas from obese women show evidence of inflammatory processes and under-perfusion, even in the absence of pre-eclampsia.[106] As early as the first trimester, obesity alters the expression of cell cycle regulatory genes in the placenta, which may impact on further placental growth and development and the capacity to maintain function at later stages of pregnancy.[107] Among the hormones secreted by the placenta are leptin and adiponectin. These adipokines influence the development of adipose tissue in the foetus. Leptin also modulates the formation of the homeostatic endocrine axes in the foetal brain. Measurements of adipokine concentrations in cord blood at birth has shown elevated concentrations with maternal obesity.[108]

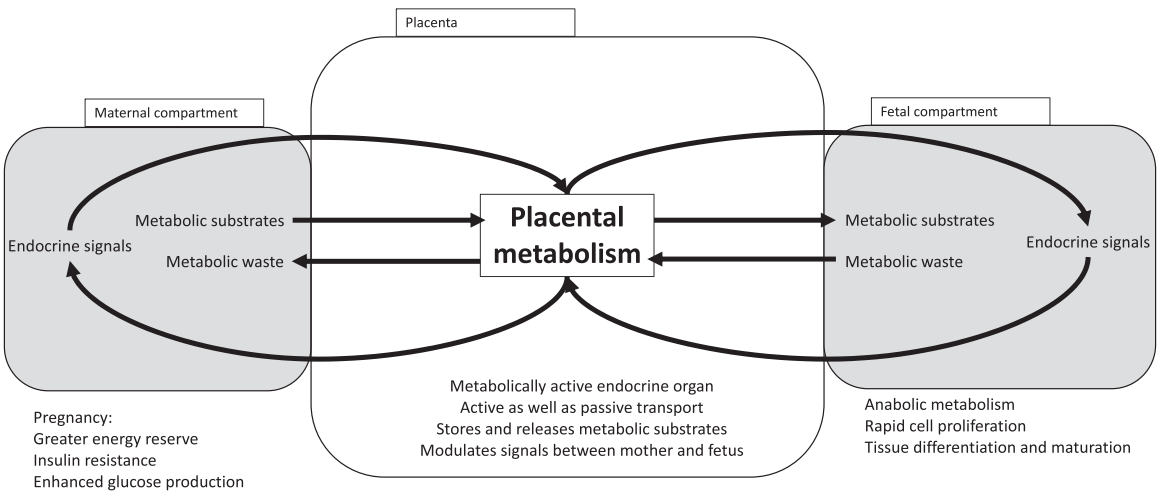

FIGURE 6 The placenta must mediate the signal of maternal nutritional status to the foetus

In addition to changes in the expression and release of endocrine signals, obesity impacts on fatty acid metabolism in the placenta. Altered expression of transcription factors and regulatory genes, including peroxisome proliferator activated receptor gamma coactivator 1 and carnitine palmitoyltransferase 1_{alpha} will impact on both lipid and carbohydrate metabolism and has been observed alongside elevated low-density lipoprotein-cholesterol and lower high-density lipoprotein-cholesterol concentrations in cord blood of foetuses exposed to maternal obesity.[109] Similarly, the observation that expression of genes that regulate placental cholesterol transport is related to maternal BMI suggests that cholesterol handling is disrupted by maternal obesity.[110] This may promote atherogenesis in the placental vessels (associated with pre-eclampsia) and disrupt steroid hormone production. Obesity impacts upon fatty acid transport by the placenta and promotes an inflammatory response.[111] The capacity of the placenta to store fatty acids is limited with obesity, resulting in greater mobilisation into the foetal compartment.[112]

Clues with respect to the mechanism of programming by maternal obesity may be gained from studies of GDM because the long-term health of offspring exposed to GDM is largely the same as that observed with maternal obesity, although obesity can occur without GDM and vice versa. As early as 2 years of age, GDM offspring exhibit markedly greater risk of obesity[113] and this persists into childhood.[114–116] Dabelea *et al.*[117] followed up sibling pairs where one of the pair had been exposed to GDM and the other had not. Among people in their early 20s, those who had experienced GDM in foetal life had a BMI on average 2.6 kg m^{-2} greater than unexposed siblings.[117] Alongside greater risk of obesity, offspring of GDM-affected pregnancies are at greater risk of metabolic disorders. Damm *et al.*[118] reported a two-fold greater risk of obesity in adults exposed to GDM *in utero*, accompanied by an eight-fold greater risk of prediabetes and diabetes than in the background population. The adverse effects of exposure to GDM may be much broader, with, for example, reports of greater prevalence of psychiatric disorders in adults whose mothers had the condition in pregnancy.[119]

A simple explanation of how GDM and possibly maternal obesity provide the insult that programmes long-term consequences for the exposed offspring is that an excess of energy substrates reaches the foetal compartment. The conventional wisdom is that this is the cause of macrosomia in GDM pregnancies because the foetus is hyperinsulinaemic and the insulin resistance of the mother drives glucose and lipids across the placenta.[8] However, this is an over-simplification because, similar to obesity, GDM has a broad impact on the placenta that will bring other factors into play. Widespread morphological changes including hypervascularisation and an increase in placental size and thickness are proposed to be a compensatory response to GDM which will preserve placental perfusion.[120] There is also an increase in placental inflammation.[121] Several defects of placental metabolism and function have been reported with GDM, including a reduction in iron transport[122] and changes to lipid metabolism.[123] With GDM, the placenta accumulates elevated concentrations of saturated fatty acids, with reduced transport of mono- and polyunsaturated fatty acids to the foetus.[123]

Although it is clear that the basic mechanisms driving the programming of health and disease by maternal obesity involve signalling across the placenta and a foetal tissue response at the level of gene and protein expression, the precise nature of the maternal signal and the foetal response in humans remain unknown. Identifying the mechanism is a high priority because, without this understanding, any intervention to prevent the long-term consequences of maternal obesity will remain solely dependent upon health education and behaviour change strategies. Experience suggests that these have limited efficacy at the population level.

IMPLICATIONS FOR THE FUTURE

The global obesity crisis will have profound consequences for the health of populations for decades to come. Obesity in adults is well recognised as a modifiable risk factor for type 2 diabetes, cardiovascular disease and many types of cancer. The evidence presented above would also suggest that the increasing numbers of individuals exposed to maternal overweight and obesity are themselves at greater risk of becoming obese and the associated cardiometabolic disorders. They will, in turn, be exposing their children to obesity *in utero*. There is a significant risk that a transgenerational cycle of obesity will be, or has already been, established (Figure 7). Such a cycle would have consequences for public health over a

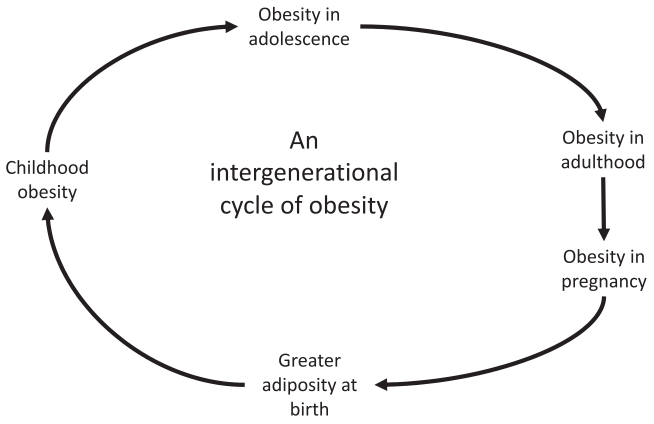

FIGURE 7 A transgenerational cycle of obesity and related disorders

century or more unless effective means can be found to break it. Importantly, as obesity rates increase most rapidly in the populations of the global south, there is a risk of an explosion of metabolic disease on an unimaginable scale in nations ill-equipped to deal with it.

Breaking such a cycle is a public health challenge of colossal complexity. The mode of intervention must be multifactorial, comprising locally tailored, culturally sensitive community education, widespread screening for predisease and investment in preventive health services. In short, a global shift in food cultures and living environments is necessary. Achieving this is unlikely, but, as the global focus moves towards sustainability, there may be opportunities to make inroads. The timing of interventions to break the transgenerational obesity cycle also needs to be considered in a more holistic manner. It is simple to think that the antenatal period is the key window for intervention. Limiting gestational weight gain and promoting a return to prepregnancy weight in the postpartum period will have many benefits. Pregnancy is perceived as a teachable moment when women are more open to public health messages and willing to make lifestyle changes,[8,124] although numerous large-scale trials show limited efficacy of, and high resistance to pregnancy-focused interventions.[125,126] The most effective approaches to managing weight gain in pregnancy appear to rely on more personalised interventions that are supported by eHealth packages and health professionals who have received appropriate training.[8,127,128] Midwives, in particular, can find it difficult to engage with women about excess weight gain[129,130] but may find it useful to have an understanding of the transgenerational consequences of antenatal obesity as they frame their conversations with women.

Recommendations on antenatal weight management are heavily focused on women making changes to diet and lifestyle before they conceive.[8] For women with extreme obesity, this might involve bariatric surgery and a number of studies demonstrate that women who achieve large weight loss through surgery have healthy pregnancies with reduced risk of complications and good outcomes.[131–133] There is an emerging literature on the effects this weight loss may have on the long-term health of babies born after weight loss. Smith *et al.*[134] compared siblings whose mothers had undergone bariatric surgery, examining health indices in those born before and after the surgery. Individuals born after weight loss surgery were born with lower birthweight and were markedly less likely to be obese than their siblings born before the surgery. There was also evidence of better insulin sensitivity, lower concentrations of inflammatory markers and adipokine concentrations that were more consistent with metabolic health.[134] However, the study only considered 49 sibling pairs and the ages of the subjects varied widely (2.6–26 years of age). The systematic review of Dunford and Sangster[135] concluded that prepregnancy weight loss results in lower body fatness and improved insulin sensitivity in children born after weight loss compared to before, and suggested that changes to DNA methylation may play a role in this. A study of 31 sibling pairs noted differential DNA methylation of genes associated with insulin receptor signalling and type-2 diabetes risk.[136] However, because the study was small and the significance of methylation differences in whole blood samples is debatable, inferring a mechanism of programming from this is premature. It is hopeful, however, that action to address weight problems before pregnancy can prevent maternal programming of adverse health in the developing foetus. A number of trials are now underway aiming to address the impact of major weight loss on long-term health and wellbeing.[137,138]

Just as health at any stage of life is dependent upon the outcomes of gene–environment interactions at all preceding life stages, there are also opportunities to intervene and break the programmed trajectory during childhood. The literature that explores the tracking of obesity from childhood to adulthood indicates that the obese child is not predestined to become an obese adult, although obesity in adolescence does appear to track strongly to the adult years.[139,140] This highlights that the childhood years are a key time to address overweight and obesity that may have been programmed *in utero*. Importantly, the evidence shows that early intervention to reverse excessive weight in childhood removes any residual metabolic risk, such that the obese child who becomes a lean adult is at no cardiometabolic disadvantage.[139,140]

Choices about infant feeding methods may represent the first point in the postnatal period when the impact of being an obese mother may be ameliorated. Systematic reviews and meta-analyses indicate that breastfeeding reduces the risk of childhood and adult obesity, with exclusive breastfeeding and breastfeeding for a longer period (up to 12 months) having greater benefits.[141] Horta *et al.*[142] showed that breastfeeding was protective against overweight and obesity in both childhood (OR = 0.74, 95% CI = 0.68–0.79) and in adults (OR = 0.88, 95% CI = 0.82–0.94). The greater risk of overweight seen in formula fed infants could result from the higher protein content of formula milks,[143] but it is also clear that breastfeeding brings advantages beyond just the milk composition. Demand-led feeding, for example, will be associated with the normal development of satiety pathways and appetite regulation, and milk contains a range of non-nutrient components. These include the appetite regulatory hormones leptin, adiponectin, resistin and ghrelin,[144] which may play a key role in establishment of appetite control in the infant hypothalamus.[145]

Although breastfeeding may represent a means of compensating against exposure to obesity *in utero*, little is known about how obesity changes the composition (nutrient and hormone) of human milk and whether

breastfeeding by an obese mother carries the same advantages as reported for the full breastfeeding population. Studies in rodents have identified that cafeteria feeding during lactation can programme offspring feeding and other behaviours, suggesting that milk may carry adverse programming signals.[65,66,146] However, the immaturity of rat pups at birth makes them very different to human infants, and so the same milk-related cues may not apply in the development of the human infant brain. Human milk is considered to be a highly dynamic food, with its composition changing according to stage of development, as well as in response to diet and time of day, and even varying between breasts in the same woman. However, much of the literature on milk composition is old and features poorly designed, small studies and little is known about how milk composition varies in response to acute changes in diet and what impact maternal adiposity may have. Leghi *et al.*[147] reported that concentrations of macronutrients in milk showed little variation over a 3-week-period. Ward *et al.*[148] found considerable diurnal variation in composition. Acutely increasing maternal fat consumption did not impact on macronutrients in milk over a 12-h period, whereas, in contrast, an increase in sugar intake resulted in a rapid increase in milk triglycerides.[148] A lot more research is required to understand what type of diet may be optimal for the production of an anti-obesogenic milk profile by women and how this may vary between women of ideal weight and those who are overweight.

The introduction of complementary foods (weaning) is another point in time where decisions may have long-term benefits for further health. The timing of weaning is considered to play an important role and, as described above, maintaining breastfeeding throughout the process prolongs exposure to human milk and the associated beneficial factors. There is evidence that very early introduction of solids (before 4 months) or delaying to beyond 6 months may increase the risk of childhood overweight.[149] The inclusion of foods rich in protein appears advantageous in terms of infant growth and body composition but, if used in complementary feeding between 2 and 12 months, the risk of overweight in childhood is increased.[150] There is a literature that considers feeding style during weaning, with some researchers advocating that a baby-led weaning approach, rather than a parent-led spoon-feeding approach, reduces risk of later obesity by allowing the infant to self-regulate intake and programme the development of satiety centres in the hypothalamus, which are not mature at birth. However, there is no significant evidence that there is a robust effect, and baby-led weaned infants may in fact self-select a diet that is high in sugars.[151–153]

To effectively meet the challenge of a transgenerational cycle of obesity and metabolic disorders, a multifaceted approach will be necessary. This needs to target: infants and children to promote healthy eating and lifestyles; adolescents to reinforce those messages before they become reproductively active; pregnant women to optimise nutrition, control weight gain and prevent GDM; and the postpartum period to promote a return to prepregnancy weight and facilitate long-term breastfeeding.[154] The emergence of evidence that paternal factors can also programme cardiometabolic health in offspring via semen-related factors means that boys as well as girls need to be the focus of optimal health behaviours for parenting.[155,156] The global increase in obesity among children and adults is a public health concern with the potential to have consequences over many generations. The growing understanding that excessive adiposity in pregnancy can threaten both the immediate and long-term health outcomes for the developing foetus should act as a stimulus for action across the world. Improving the nutrition and understanding of young people aiming to optimise their reproductive fitness will be a considerable challenge in the face of other societal and population health issues, but should be regarded as a high priority.

AUTHOR CONTRIBUTIONS

Simon C. Langley-Evans is responsible for the inception and writing of this review.

ACKNOWLEDGEMENTS

No funding was received.

CONFLICTS OF INTEREST

The author declares that there are no conflicts of interest.

TRANSPARENCY DECLARATION

The lead author affirms that this manuscript is an honest, accurate and transparent account of the study being reported.

ORCID

Simon C. Langley-Evans http://orcid.org/0000-0002-1969-8416

REFERENCES

1. Doll R, Peto R. Cigarette smoking and bronchial carcinoma: dose and time relationships among regular smokers and lifelong non-smokers. J Epidemiol Community Health. 1978;32:303–13.
2. Keys A, Anderson JT, Grande F. Serum cholesterol response to changes in the diet: II. The effect of cholesterol in the diet. Metabolism. 1965;14:759–65.
3. Goldstein JL, Brown MS. The low-density lipoprotein pathway and its relation to atherosclerosis. Annu Rev Biochem. 1977;46:897–930.
4. Münzel T, Sørensen M, Lelieveld J, Hahad O, Al-Kindi S, Nieuwenhuijsen M, et al. Heart healthy cities: genetics loads the gun but the environment pulls the trigger. Eur Heart J. 2021;42:2422–38.
5. Calder PC, Carding SR, Christopher G, Kuh D, Langley-Evans SC, McNulty H. A holistic approach to healthy ageing: how can people live longer, healthier lives? J Hum Nutr Diet. 2018;31:439–50.

6. Langley-Evans SC. Nutrition in early life and the programming of adult disease: a review. J Hum Nutr Diet. 2015;28(Suppl 1): 1–14.
7. Ritchie H, Roser M 'Obesity'. 2017 [cited 2022 February 14]. Available from: https://ourworldindata.org/obesity
8. Langley-Evans SC, Ellis S. Overweight, obesity and excessive weight gain in pregnancy as risk factors for adverse pregnancy outcomes. J Hum Nutr Diet. 2022;35:250–64.
9. Institute of Medicine. Weight Gain during pregnancy: reexamining the guidelines. Washington, DC: National Academies Press; 2009.
10. Pan Y, Zhang S, Wang Q, Shen H, Zhang Y, Li Y, et al. Investigating the association between prepregnancy body mass index and adverse pregnancy outcomes: a large cohort study of 536 098 Chinese pregnant women in rural China. BMJ Open. 2016;6:e011227.
11. Aune D, Saugstad OD, Henriksen T, Tonstad S. Maternal body mass index and the risk of fetal death, stillbirth, and infant death: a systematic review and meta-analysis. JAMA. 2014;311: 1536–46.
12. Platner MH, Ackerman CM, Howland RE, Illuzzi J, Reddy UM, Bourjeily G, et al. Severe maternal morbidity and mortality during delivery hospitalization of class I, II, III, and super obese women. Am J Obstet Gynecol MFM. 2021;3:100420.
13. Denison FC, Norrie G, Graham B, Lynch J, Harper N, Reynolds RM. Increased maternal BMI is associated with an increased risk of minor complications during pregnancy with consequent cost implications. BJOG. 2009;116:1467–72.
14. Relph S, Guo Y, Harvey ALJ, Vieira MC, Corsi DJ, Gaudet LM, et al. Characteristics associated with uncomplicated pregnancies in women with obesity: a population-based cohort study. BMC Pregnancy Childbirth. 2021;21:182.
15. Alwash SM, McIntyre HD, Mamun A. The association of general obesity, central obesity and visceral body fat with the risk of gestational diabetes mellitus: evidence from a systematic review and meta-analysis. Obes Res Clin Pract. 2021;15:425–30.
16. He XJ, Dai RX, Hu CL. Maternal prepregnancy overweight and obesity and the risk of preeclampsia: a meta-analysis of cohort studies. Obes Res Clin Pract. 2020;14:27–33.
17. Hadden DR. Prediabetes and the big baby. Diabetic Med. 2008; 25:1–10.
18. Williams AJ, Marryat L, Frank J. Cohort study of high maternal body mass index and the risk of adverse pregnancy and delivery outcomes in Scotland. BMJ Open. 2020;10:e026168.
19. Marchi J, Berg M, Dencker A, Olander EK, Begley C. Risks associated with obesity in pregnancy, for the mother and baby: a systematic review of reviews. Obes Rev. 2015;16:621–38.
20. Dalbye R, Gunnes N, Blix E. Maternal body mass index and risk of obstetric, maternal and neonatal outcomes: a cohort study of nulliparous women with spontaneous onset of labor. Acta Obstet Gynecol Scand. 2021;100:521–30.
21. Osmond C, Barker DJ, Slattery JM. Risk of death from cardiovascular disease and chronic bronchitis determined by place of birth in England and Wales. J Epidemiol Community Health. 1990;44:139–41.
22. Barker DJ, Osmond C. Infant mortality, childhood nutrition, and ischaemic heart disease in England and Wales. Lancet. 1986; 1:1077–81.
23. Barker DJ, Winter PD, Osmond C, Margetts B, Simmonds SJ. Weight in infancy and death from ischaemic heart disease. Lancet. 1989;2:577–80.
24. Leon DA, Lithell HO, Vâgerö D, Koupilová I, Mohsen R, Berglund L, et al. Reduced fetal growth rate and increased risk of death from ischaemic heart disease: cohort study of 15 000 Swedish men and women born 1915–29. BMJ. 1998;317: 241–5.
25. Rich-Edwards JW, Stampfer MJ, Manson JE, Rosner B, Hankinson SE, Colditz GA, et al. Birth weight and risk of cardiovascular disease in a cohort of women followed up since 1976. BMJ. 1997;315:396–400.
26. Yajnik CS, Fall CH, Vaidya U, Pandit AN, Bavdekar A, Bhat DS, et al. Fetal growth and glucose and insulin metabolism in four-year-old Indian children. Diabet Med. 1995;12:330–6.
27. Barker DJ, Hales CN, Fall CH, Osmond C, Phipps K, Clark PM. Type 2 (non-insulin-dependent) diabetes mellitus, hypertension and hyperlipidaemia (syndrome X): relation to reduced fetal growth. Diabetologia. 1993;36:62–7.
28. Hales CN, Barker DJ, Clark PM, Cox LJ, Fall C, Osmond C, et al. Fetal and infant growth and impaired glucose tolerance at age 64. BMJ. 1991;303:1019–22.
29. Whincup PH, Kaye SJ, Owen CG, Huxley R, Cook DG, Anazawa S, et al. Birth weight and risk of type 2 diabetes: a systematic review. JAMA. 2008;300:2886–97.
30. Carrington LJ, Langley-Evans SC. Wheezing and eczema in relation to infant anthropometry: evidence of developmental programming of disease in childhood. Matern Child Nutr. 2006; 2:51–61.
31. Lithell HO, McKeigue PM, Berglund L, Mohsen R, Lithell UB, Leon DA. Relation of size at birth to non-insulin dependent diabetes and insulin concentrations in men aged 50-60 years.BMJ. 1996;312:406–10.
32. Barker DJ, Martyn CN, Osmond C, Wield GA. Abnormal liver growth in utero and death from coronary heart disease. BMJ. 1995;310:703–4.
33. Phillips DI, Barker DJ, Hales CN, Hirst S, Osmond C. Thinness at birth and insulin resistance in adult life. Diabetologia. 1994;37: 150–4.
34. Forsén T, Eriksson JG, Tuomilehto J, Osmond C, Barker DJ. Growth in utero and during childhood among women who develop coronary heart disease: longitudinal study. BMJ. 1999; 319:1403–7.
35. Eriksson JG, Lindi V, Uusitupa M, Forsén TJ, Laakso M, Osmond C, et al. The effects of the Pro12Ala polymorphism of the peroxisome proliferator-activated receptor-gamma2 gene on insulin sensitivity and insulin metabolism interact with size at birth. Diabetes. 2002;51:2321–4.
36. Eriksson J, Lindi V, Uusitupa M, Forsén T, Laakso M, Osmond C, et al. The effects of the Pro12Ala polymorphism of the PPARgamma-2 gene on lipid metabolism interact with body size at birth. Clin Genet. 2003;64:366–70.
37. Roseboom TJ, Painter RC, van Abeelen AF, Veenendaal MV, de Rooij SR. Hungry in the womb: what are the consequences? Lessons from the Dutch famine. Maturitas. 2011;70:141–5.
38. de Rooij SR, Roseboom TJ, Painter RC. Famines in the last 100 years: implications for diabetes. Curr Diab Rep. 2014;14:536.
39. Meng R, Yu C, Guo Y, Bian Z, Si J, Nie J, et al. Early famine exposure and adult disease risk based on a 10-year prospective study of Chinese adults. Heart. 2020;106:213–20.
40. Liu J, Wang G, Wu Y, Guan Y, Luo Z, Zhao G, et al. Early-life exposure to famine and risk of metabolic associated fatty liver disease in Chinese adults. Nutrients. 2021;13:4063.
41. Wang B, Cheng J, Wan H, Wang Y, Zhang W, Chen Y, et al. Early-life exposure to the Chinese famine, genetic susceptibility and the risk of type 2 diabetes in adulthood. Diabetologia. 2021; 64:1766–74.
42. Huang YQ, Liu L, Yu YL, Lo K, Chen CL, Huang JY, et al. The relationship between famine exposure in early life and left atrial enlargement in adulthood. J Hum Nutr Diet. 2021;34:356–64.
43. Hales CN, Barker DJ. The thrifty phenotype hypothesis. Br Med Bull. 2001;60:5–20.
44. Bateson P, Gluckman P, Hanson M. The biology of developmental plasticity and the predictive adaptive response hypothesis. J Physiol. 2014;592:2357–68.
45. Hattersley AT, Tooke JE. The fetal insulin hypothesis: an alternative explanation of the association of low birthweight with diabetes and vascular disease. Lancet. 1999;353:1789–92.

46. Warrington NM, Beaumont RN, Horikoshi M, Day FR, Helgeland Ø, Laurin C, et al. Maternal and fetal genetic effects on birth weight and their relevance to cardio-metabolic risk factors. Nat Genet. 2019;51:804–14.
47. Langley-Evans SC. Fetal programming of CVD and renal disease: animal models and mechanistic considerations. Proc Nutr Soc. 2013;72:317–25.
48. Inskip HM, Godfrey KM, Robinson SM, Law CM, Barker DJ, Cooper C, et al. Cohort profile: the Southampton Women's Survey. Int J Epidemiol. 2006;35:42–8.
49. Soh SE, Tint MT, Gluckman PD, Godfrey KM, Rifkin-Graboi A, Chan YH, et al. Cohort profile: Growing Up in Singapore Towards healthy Outcomes (GUSTO) birth cohort study. Int J Epidemiol. 2014;43:1401–9.
50. Oken E, Baccarelli AA, Gold DR, Kleinman KP, Litonjua AA, De Meo D, et al. Cohort profile: project viva. Int J Epidemiol. 2015;44:37–48.
51. McMullen S, Mostyn A. Animal models for the study of the developmental origins of health and disease. Proc Nutr Soc. 2009;68:306–20.
52. Kuo AH, Li C, Li J, Huber HF, Nathanielsz PW, Clarke GD. Cardiac remodelling in a baboon model of intrauterine growth restriction mimics accelerated ageing. J Physiol. 2017;595: 1093–110.
53. Joles JA, Sculley DV, Langley-Evans SC. Proteinuria in aging rats due to low-protein diet during mid-gestation. J Dev Orig Health Dis. 2010;1(1):75–83.
54. Langley-Evans SC, Sculley DV. The association between birthweight and longevity in the rat is complex and modulated by maternal protein intake during fetal life. FEBS Lett. 2006;580: 4150–3.
55. Bellinger L, Sculley DV, Langley-Evans SC. Exposure to undernutrition in fetal life determines fat distribution, locomotor activity and food intake in ageing rats. Int J Obes (Lond). 2006; 30:729–38.
56. Erhuma A, Salter AM, Sculley DV, Langley-Evans SC, Bennett AJ. Prenatal exposure to a low-protein diet programs disordered regulation of lipid metabolism in the aging rat. Am J Physiol Endocrinol Metab. 2007;292:E1702–14.
57. Vickers MH, Breier BH, Cutfield WS, Hofman PL, Gluckman PD. Fetal origins of hyperphagia, obesity, and hypertension and postnatal amplification by hypercaloric nutrition. Am J Physiol Endocrinol Metab. 2000;279:E83–7.
58. Yates Z, Tarling EJ, Langley-Evans SC, Salter AM. Maternal undernutrition programmes atherosclerosis in the ApoE*3-Leiden mouse. Br J Nutr. 2009;101:1185–94.
59. Sampey BP, Vanhoose AM, Winfield HM, Freemerman AJ, Muehlbauer MJ, Fueger PT, et al. Cafeteria diet is a robust model of human metabolic syndrome with liver and adipose inflammation: comparison to high-fat diet. Obesity (Silver Spring). 2011;19(6):1109–17.
60. Samuelsson AM, Matthews PA, Argenton M, Christie MR, McConnell JM, Jansen EH, et al. Diet-induced obesity in female mice leads to offspring hyperphagia, adiposity, hypertension, and insulin resistance: a novel murine model of developmental programming. Hypertension. 2008;51:383–92.
61. Akyol A, McMullen S, Langley-Evans SC. Glucose intolerance associated with early-life exposure to maternal cafeteria feeding is dependent upon post-weaning diet. Br J Nutr. 2012;107: 964–78.
62. Vithayathil MA, Gugusheff JR, Ong ZY, Langley-Evans SC, Gibson RA, Muhlhausler BS. Exposure to maternal cafeteria diets during the suckling period has greater effects on fat deposition and Sterol Regulatory Element Binding Protein-1c (SREBP-1c) gene expression in rodent offspring compared to exposure before birth. Nutr Metab (Lond). 2018;15:17.
63. George G, Draycott SAV, Muir R, Clifford B, Elmes MJ, Langley-Evans SC. The impact of exposure to cafeteria diet during pregnancy or lactation on offspring growth and adiposity before weaning. Sci Rep. 2019;9:14173.
64. George G, Draycott SAV, Muir R, Clifford B, Elmes MJ, Langley-Evans SC. Exposure to maternal obesity during suckling outweighs in utero exposure in programming for post-weaning adiposity and insulin resistance in rats. Sci Rep. 2019;9:10134.
65. Wright T, Langley-Evans SC, Voigt JP. The impact of maternal cafeteria diet on anxiety-related behaviour and exploration in the offspring. Physiol Behav. 2011;103:164–72.
66. Wright TM, Fone KC, Langley-Evans SC, Voigt JP. Exposure to maternal consumption of cafeteria diet during the lactation period programmes feeding behaviour in the rat. Int J Dev Neurosci. 2011;29:785–93.
67. Campodonico-Burnett W, Hetrick B, Wesolowski SR, Schenk S, Takahashi DL, Dean TA, et al. Maternal obesity and western-style diet impair fetal and juvenile offspring skeletal muscle insulin-stimulated glucose transport in nonhuman primates. Diabetes. 2020;69:1389–400.
68. Elsakr JM, Dunn JC, Tennant K, Zhao SK, Kroeten K, Pasek RC, et al. Maternal Western-style diet affects offspring islet composition and function in a non-human primate model of maternal over-nutrition. Mol Metab. 2019;25:73–82.
69. Whitaker RC, Wright JA, Pepe MS, Seidel KD, Dietz WH. Predicting obesity in young adulthood from childhood and parental obesity. N Engl J Med. 1997;337:869–73.
70. Parsons TJ, Power C, Manor O. Fetal and early life growth and body mass index from birth to early adulthood in 1958 British cohort: longitudinal study. BMJ. 2001;323:1331–5.
71. Laitinen J, Pietiläinen K, Wadsworth M, Sovio U, Järvelin MR. Predictors of abdominal obesity among 31-y-old men and women born in Northern Finland in 1966. Eur J Clin Nutr. 2004;58:180–90.
72. Catalano PM, Ehrenberg HM. The short- and long-term implications of maternal obesity on the mother and her offspring. BJOG. 2006;113:1126–33.
73. Gillman MW, Rifas-Shiman S, Berkey CS, Field AE, Colditz GA. Maternal gestational diabetes, birth weight, and adolescent obesity. Pediatrics. 2003;111:e221–6.
74. Dhana K, Haines J, Liu G, Zhang C, Wang X, Field AE, et al. Association between maternal adherence to healthy lifestyle practices and risk of obesity in offspring: results from two prospective cohort studies of mother-child pairs in the United States. BMJ. 2018;362:k2486.
75. Catalano PM, Presley L, Minium J, Hauguel-de Mouzon S. Fetuses of obese mothers develop insulin resistance in utero. Diabetes Care. 2009;32:1076–80.
76. Mingrone G, Manco M, Mora ME, Guidone C, Iaconelli A, Gniuli D, et al. Influence of maternal obesity on insulin sensitivity and secretion in offspring. Diabetes Care. 2008;31: 1872187–6.
77. Tan HC, Roberts J, Catov J, Krishnamurthy R, Shypailo R, Bacha F. Mother's pre-pregnancy BMI is an important determinant of adverse cardiometabolic risk in childhood. Pediatr Diabetes. 2015;16:419–26.
78. Ounjaijean S, Wongthanee A, Kulprachakarn K, Rerkasem A, Pruenglampoo S, Mangklabruks A, et al. Higher maternal BMI early in pregnancy is associated with overweight and obesity in young adult offspring in Thailand. BMC Public Health. 2021;21: 724.
79. Razaz N, Villamor E, Muraca GM, Bonamy AE, Cnattingius S. Maternal obesity and risk of cardiovascular diseases in offspring: a population-based cohort and sibling-controlled study. Lancet Diabetes Endocrinol. 2020;8:572–81.
80. Eriksson JG, Sandboge S, Salonen MK, Kajantie E, Osmond C. Long-term consequences of maternal overweight in pregnancy on offspring later health: findings from the Helsinki Birth Cohort Study. Ann Med. 2014;46:434–8.

81. Reynolds RM, Allan KM, Raja EA, Bhattacharya S, McNeill G, Hannaford PC, et al. Maternal obesity during pregnancy and premature mortality from cardiovascular event in adult offspring: follow-up of 1 323 275 person years. BMJ. 2013;347: f4539.
82. Boney CM, Verma A, Tucker R, Vohr BR. Metabolic syndrome in childhood: association with birth weight, maternal obesity, and gestational diabetes mellitus. Pediatrics. 2005;115: e290–6.
83. Bucci M, Huovinen V, Guzzardi MA, Koskinen S, Raiko JR, Lipponen H, et al. Resistance training improves skeletal muscle insulin sensitivity in elderly offspring of overweight and obese mothers. Diabetologia. 2016;59:77–86.
84. Lahti-Pulkkinen M, Räikkönen K, Bhattacharya S, Reynolds RM. Maternal body mass index in pregnancy and mental disorders in adult offspring: a record linkage study in Aberdeen, Scotland. Sci Rep. 2021;11:15132.
85. Hussen HI, Persson M, Moradi T. Maternal overweight and obesity are associated with increased risk of type 1 diabetes in offspring of parents without diabetes regardless of ethnicity. Diabetologia. 2015;58:1464–73.
86. Arkkola T, Kautiainen S, Takkinen, Kenward MG, Nevalainen J, Uusitalo U, et al. Relationship of maternal weight status and weight gain rate during pregnancy to the development of advanced beta cell autoimmunity in the offspring: a prospective birth cohort study. Pediatr Diabetes. 2011;12: 478–84.
87. Stene LC, Magnus P, Lie RT, Sovik O, Joner G. Birth weight and childhood onset type 1 diabetes: population based cohort study. BMJ. 2001;322:889–92.
88. Rasmussen T, Stene LC, Samuelsen, Cinek O, Wetlesen T, Torjesen PA, et al. Maternal BMI before pregnancy, maternal weight gain during pregnancy, and risk of persistent positivity for multiple diabetes-associated autoantibodies in children with the high-risk HLA genotype: the MIDIA study. Diabetes Care. 2009;32:1904–06.
89. Arkkola T, Kautiainen S, Takkinen, Kenward MG, Nevalainen J, Uusitalo U, et al. Relationship of maternal weight status and weight gain rate during pregnancy to the development of advanced beta cell autoimmunity in the offspring: a prospective birth cohort study. Pediatr Diabetes. 2011;12: 478–84.
90. Lee YQ, Lumbers ER, Oldmeadow C, Collins CE, Johnson V, Keogh L, et al. The relationship between maternal adiposity during pregnancy and fetal kidney development and kidney function in infants: the Gomeroi gaaynggal study. Physiol Rep. 2019;7:e14227.
91. Patel SP, Rodriguez A, Little MP, Elliott P, Pekkanen J, Hartikainen AL, et al. Associations between pre-pregnancy obesity and asthma symptoms in adolescents. J Epidemiol Community Health. 2012;66:809–14.
92. Kaseva N, Vääräsmäki M, Matinolli HM, Sipola M, Tikanmäki M, Kanerva N, et al. Maternal pre-pregnancy overweight and gestational diabetes and dietary intakes among young adult offspring. Nutr Diabetes. 2020;10:26.
93. Brion MJ, Ness AR, Rogers I, Emmett P, Cribb V, Davey Smith G, et al. Maternal macronutrient and energy intakes in pregnancy and offspring intake at 10 y: exploring parental comparisons and prenatal effects. Am J Clin Nutr. 2010; 91:748–56.
94. Leary SD, Lawlor DA, Davey Smith G, Brion MJ, Ness AR. Behavioural early-life exposures and body composition at age 15 years. Nutr Diabetes. 2015;5:e150.
95. Wardle J, Guthrie C, Sanderson S, Birch L, Plomin R. Food and activity preferences in children of lean and obese parents. Int J Obes Relat Metab Disord. 2001;25:971–7.
96. Bayol SA, Simbi BH, Stickland NC. A maternal cafeteria diet during gestation and lactation promotes adiposity and impairs skeletal muscle development and metabolism in rat offspring at weaning. J Physiol. 2005;567:951–61.
97. Bayol SA, Farrington SJ, Stickland NC. A maternal 'junk food' diet in pregnancy and lactation promotes an exacerbated taste for 'junk food' and a greater propensity for obesity in rat offspring. Br J Nutr. 2007;98:843–51.
98. Langley-Evans SC, Welham SJ, Jackson AA. Fetal exposure to a maternal low protein diet impairs nephrogenesis and promotes hypertension in the rat. Life Sci. 1999;64:965–74.
99. Plagemann A, Harder T, Rake A, Melchior K, Rohde W, Dörner G. Hypothalamic nuclei are malformed in weanling offspring of low protein malnourished rat dams. J Nutr. 2000; 130:2582–9.
100. Snoeck A, Remacle C, Reusens B, Hoet JJ. Effect of a low protein diet during pregnancy on the fetal rat endocrine pancreas. Biol Neonate. 1990;57:107–18.
101. Lumbers ER, Kandasamy Y, Delforce SJ, Boyce AC, Gibson KJ, Pringle KG. Programming of renal development and chronic disease in adult life. Front Physiol. 2020;11:757.
102. Hughson M, Farris AB, Douglas-Denton R, Hoy WE, Bertram JF. Glomerular number and size in autopsy kidneys: the relationship to birth weight. Kidney Int. 2003;63:2113–22.
103. Luyckx VA, Perico N, Somaschini M, Manfellotto D, Valensise H, Cetin I, et al. A developmental approach to the prevention of hypertension and kidney disease: a report from the Low Birth Weight and Nephron Number Working Group. Lancet. 2017;390:424–8.
104. Lamminpää R, Vehviläinen-Julkunen K, Gissler M, Selander T, Heinonen S. Pregnancy outcomes of overweight and obese women aged 35 years or older - a registry-based study in Finland. Obes Res Clin Pract. 2016;10:133–42.
105. Poston L. Endothelial dysfunction in pre-eclampsia. Pharmacol Rep. 2006;58(Suppl):69–74.
106. Brouwers L, Franx A, Vogelvang TE, Houben ML, van Rijn BB, Nikkels PG. Association of maternal prepregnancy body mass index with placental histopathological characteristics in uncomplicated term pregnancies. Pediatr Dev Pathol. 2019;22: 45–52.
107. Hoch D, Bachbauer M, Pöchlauer C, Algaba-Chueca F, Tandl V, Novakovic B, et al. Maternal obesity alters placental cell cycle regulators in the first trimester of human pregnancy: new insights for BRCA1. Int J Mol Sci. 2020;21:468.
108. Jaramillo-Ospina Á, Castaño-Moreno E, Muñoz-Muñoz E, Krause BJ, Uauy R, Casanello P, et al. Maternal obesity is associated with higher cord blood adipokines in offspring most notably in females. J Pediatr Gastroenterol Nutr. 2021;73: 264–70.
109. Bucher M, Montaniel KRC, Myatt L, Weintraub S, Tavori H, Maloyan A. Dyslipidemia, insulin resistance, and impairment of placental metabolism in the offspring of obese mothers. J Dev Orig Health Dis. 2021;12:738–47.
110. Draycott SAV, Daniel Z, Khan R, Muhlhausler BS, Elmes MJ, Langley-Evans SC. Expression of cholesterol packaging and transport genes in human and rat placenta: impact of obesity and a high-fat diet. J Dev Orig Health Dis. 2020;11:222–7.
111. Belcastro L, Ferreira CS, Saraiva MA, Mucci DB, Murgia A, Lai C, et al. Nutrients. 2021;13:2768.
112. Hirschmugl B, Perazzolo S, Sengers BG, Lewis RM, Gruber M, Desoye G, et al. Placental mobilization of free fatty acids contributes to altered materno-fetal transfer in obesity. Int J Obes (Lond). 2021;45:1114–23.
113. Zou J, Yang Y, Wei Q, Zhang Y, Shi H. Longitudinal association of maternal pre-pregnancy BMI and third-trimester glycemia with early life growth of offspring: a prospective study among GDM-negative pregnant women. Nutrients. 2021;13: 3971.
114. Norris T, Mansukoski L, Gilthorpe MS, Hamer M, Hardy R, Howe LD, et al. Early childhood weight gain: latent patterns and

body composition outcomes. Paediatr Perinat Epidemiol. 2021; 35:557–68.
115. Loo EXL, Zhang Y, Yap QV, Yu G, Soh SE, Loy SL, et al. Comparative epidemiology of gestational diabetes in ethnic Chinese from Shanghai birth cohort and growing up in Singapore towards healthy outcomes cohort. BMC Pregnancy Childbirth. 2021;21:566.
116. Chivese T, Haynes MC, van Zyl H, Kyriacos U, Levitt NS, Norris SA. The influence of maternal blood glucose during pregnancy on weight outcomes at birth and preschool age in offspring exposed to hyperglycemia first detected during pregnancy, in a South African cohort. PLoS One. 2021;16: e0258894.
117. Dabelea D, Hanson RL, Lindsay RS, Pettitt DJ, Imperatore G, Gabir MM, et al. Intrauterine exposure to diabetes conveys risks for type 2 diabetes and obesity: a study of discordant sibships. Diabetes. 2000;49:2208–11.
118. Damm P, Houshmand-Oeregaard A, Kelstrup L, Lauenborg J, Mathiesen ER, Clausen TD. Gestational diabetes mellitus and long-term consequences for mother and offspring: a view from Denmark. Diabetologia. 2016;59:1396–9.
119. Nogueira Avelar E, Silva R, Yu Y, Liew Z, Vested A, Sørensen HT, et al. Associations of maternal diabetes during pregnancy with psychiatric disorders in offspring during the first 4 decades of life in a population-based Danish birth cohort. JAMA Netw Open. 2021;4:e2128005.
120. Carrasco-Wong I, Moller A, Giachini FR, Lima VV, Toledo F, Stojanova J, et al. Placental structure in gestational diabetes mellitus. Biochim Biophys Acta, Mol Basis Dis. 2020;1866: 165535.
121. Li YX, Long DL, Liu J, Qiu D, Wang J, Cheng X, et al. Gestational diabetes mellitus in women increased the risk of neonatal infection via inflammation and autophagy in the placenta. Medicine (Baltimore). 2020;99:e22152.
122. Zaugg J, Melhem H, Huang X, Wegner M, Baumann M, Surbek D, et al. Gestational diabetes mellitus affects placental iron homeostasis: mechanism and clinical implications. FASEB J. 2020;34:7311–29.
123. Stirm L, Kovárová M, Perschbacher S, Michlmaier R, Fritsche L, Siegel-Axel D, et al. BMI-independent effects of gestational diabetes on human placenta. J Clin Endocrinol Metab. 2018;103:3299–309.
124. Phelan S. Pregnancy: a 'teachable moment' for weight control and obesity prevention. Am J Obstet Gynecol. 2010;202(135): e1–8.
125. Dodd JM, McPhee AJ, Turnbull D, Yelland LN, Deussen AR, Grivell RM, et al. The effects of antenatal dietary and lifestyle advice for women who are overweight or obese on neonatal health outcomes: the LIMIT randomised trial. BMC Med. 2014; 12:163.
126. Poston L, Bell R, Croker H, Flynn AC, Godfrey KM, Goff L, et al. Effect of a behavioural intervention in obese pregnant women (the UPBEAT study): a multicentre, randomised controlled trial. Lancet Diabetes Endocrinol. 2015;3:767–77.
127. Lawrence W, Vogel C, Strömmer S, Morris T, Treadgold B, Watson D, et al. How can we best use opportunities provided by routine maternity care to engage women in improving their diets and health? Matern Child Nutr. 2020;16:e12900.
128. Downs DS, Savage JS, Rivera DE, Pauley AM, Leonard KS, Hohman EE, et al. Adaptive, behavioral intervention impact on weight gain, physical activity, energy intake, and motivational determinants: results of a feasibility trial in pregnant women with overweight/obesity. J Behav Med. 2021;44:605–21.
129. Soltani H, Duxbury A, Rundle R, Marvin-Dowle K. Dietary habits and supplementation practices of young women during pregnancy: an online cross-sectional survey of young mothers and health care professionals. BMC Nutr. 2017;3:19.
130. Heslehurst N, Lang R, Rankin J, Wilkinson HR, Summerbell CD. Obesity in pregnancy: a study of the impact of maternal obesity on NHS maternity services. BJOG. 2007;114: 334–42.
131. Maslin K, Douek I, Greenslade B, Shawe J. Nutritional and perinatal outcomes of pregnant women with a history of bariatric surgery: a case series from a UK centre. J Hum Nutr Diet. 2020;33:386–95.
132. Johansson K, Cnattingius S, Näslund I, Roos N, Trolle Lagerros Y, Granath F, et al. Outcomes of pregnancy after bariatric surgery. N Engl J Med. 2015;372(9):814–24.
133. Galazis N, Docheva N, Simillis C, Nicolaides KH. Maternal and neonatal outcomes in women undergoing bariatric surgery: a systematic review and meta-analysis. Eur J Obstet Gynecol Reprod Biol. 2014;181:45–53.
134. Smith J, Cianflone K, Biron S, Hould FS, Lebel S, Marceau S, et al. Effects of maternal surgical weight loss in mothers on intergenerational transmission of obesity. J Clin Endocrinol Metab. 2009;94:4275–83.
135. Dunford AR, Sangster JM. Maternal and paternal periconceptional nutrition as an indicator of offspring metabolic syndrome risk in later life through epigenetic imprinting: a systematic review. Diabetes Metab Syndr. 11. 2017; 181(Suppl 2):S655–62.
136. Berglind D, Müller P, Willmer M, Sinha I, Tynelius P, Näslund E, et al. Differential methylation in inflammation and type 2 diabetes genes in siblings born before and after maternal bariatric surgery. Obesity. 2016;24:250–61.
137. Van De Maele K, Gies I, Devlieger R. Effect of bariatric surgery before pregnancy on the vascular function in the offspring: protocol of a cross-sectional follow-up study. BMJ Paediatr Open. 2019;3:e000405.
138. Price S, Nankervis A, Permezel M, Prendergast L, Sumithran P, Proietto J. Health consequences for mother and baby of substantial pre-conception weight loss in obese women: study protocol for a randomized controlled trial. Trials. 2018;19:248.
139. Lloyd LJ, Langley-Evans SC, McMullen S. Childhood obesity and risk of the adult metabolic syndrome: a systematic review. Int J Obes (Lond). 2012;36:1–11.
140. Lloyd LJ, Langley-Evans SC, McMullen S. Childhood obesity and adult cardiovascular disease risk: a systematic review. Int J Obes (Lond). 2010;34:18–28.
141. Arenz S, Rückerl R, Koletzko B, von Kries R. Breast-feeding and childhood obesity-a systematic review. Int J Obes Relat Metab Disord. 2004;28:1247–56.
142. Horta BL, Loret de Mola C, Victora CG. Long-term consequences of breastfeeding on cholesterol, obesity, systolic blood pressure and type 2 diabetes: a systematic review and meta-analysis. Acta Paediatr. 2015;104:30–7.
143. Koletzko B, von Kries R, Closa R, Escribano J, Scaglioni S, Giovannini M, et al. Lower protein in infant formula is associated with lower weight up to age 2 y: a randomized clinical trial. Am J Clin Nutr. 2009;89:1836–45.
144. Ballard O, Morrow AL. Human milk composition: nutrients and bioactive factors. Pediatr Clin North Am. 2013;60:49–74.
145. Bouret SG, Simerly RB. Minireview: Leptin and development of hypothalamic feeding circuits. Endocrinology. 2004;145:2621–6.
146. Warneke W, Klaus S, Fink H, Langley-Evans SC, Voigt JP. The impact of cafeteria diet feeding on physiology and anxiety-related behaviour in male and female Sprague-Dawley rats of different ages. Pharmacol Biochem Behav. 2014;116:45–54.
147. Leghi GE, Lai CT, Narayanan A, Netting MJ, Dymock M, Rea A, et al. Daily variation of macronutrient concentrations in mature human milk over 3 weeks. Sci Rep. 2021;11:10224.
148. Ward E, Yang N, Muhlhausler BS, Leghi GE, Netting MJ, Elmes MJ, et al. Acute changes to breast milk composition following consumption of high-fat and high-sugar meals. Matern Child Nutr. 2021;17:e13168.

149. Pearce J, Taylor MA, Langley-Evans SC. Timing of the introduction of complementary feeding and risk of childhood obesity: a systematic review. Int J Obes (Lond). 2013;37:1295–306.
150. Pearce J, Langley-Evans SC. The types of food introduced during complementary feeding and risk of childhood obesity: a systematic review. Int J Obes (Lond). 2013;37:477–85.
151. Pearce J, Langley-Evans SC. Comparison of food and nutrient intake in infants aged 6-12 months, following baby-led or traditional weaning: a cross-sectional study. J Hum Nutr Diet. 2022;35:310–24.
152. Rowan H, Lee M, Brown A. Estimated energy and nutrient intakes for infants following baby-led and traditional weaning approaches. J Hum Nutr Diet. 2022;35(2):325–36.https://doi.org/10.1111/jhn.12981
153. Langley-Evans SC. Complementary feeding: should baby be leading the way? J Hum Nutr Diet. 2022;35:247–9.
154. Ma RCW, Popkin BM. Intergenerational diabetes and obesity - a cycle to break? PLoS Med. 2017;14:e1002415.
155. Hieronimus B, Ensenauer R. Influence of maternal and paternal pre-conception overweight/obesity on offspring outcomes and strategies for prevention. Eur J Clin Nutr. 2021;75:1735–44.
156. Su L, Patti ME. Paternal nongenetic intergenerational transmission of metabolic disease risk. Curr Diab Rep. 2019;19:38.

AUTHOR BIOGRAPHY

Simon C. Langley-Evans BSc, PhD, DSc is Professor of Human Nutrition at the University of Nottingham. His research focus is on maternal and infant nutrition, including the early life origins of health and disease.

How to cite this article: Langley-Evans SC. Early life programming of health and disease: The long-term consequences of obesity in pregnancy. J Hum Nutr Diet. 2022;35:816–832. https://doi.org/10.1111/jhn.13023

Received: 27 August 2021 | Accepted: 4 January 2022

DOI: 10.1111/jhn.12993

JHND Journal of Human Nutrition and Dietetics | BDA The Association of UK Dietitians

Development of affective learning in dietetics graduates: A qualitative longitudinal study

Marie-Claire O'Shea[1] | **Claire Palermo**[2] | **Gary D. Rogers**[3] | **Lauren T. Williams**[4]

[1]School of Health Sciences & Social Work, Griffith University, Southport, QLD, Australia

[2]Monash Centre for Scholarship in Health Education, Monash University, Clayton, VIC, Australia

[3]School of Medicine, Deakin University, Geelong, Melbourne, VIC, Australia

[4]Menzies Health Institute of Queensland, Griffith University, Southport, QLD, Australia

Correspondence
Marie-Claire O'Shea, School of Health Sciences & Social Work, Griffith University, Parklands Drive, Southport, QLD 4222, Australia.
Email: m.oshea@griffith.edu.au

Abstract

Background: The development of affective learning during healthcare student education is essential for professional practice. Current studies are limited to short-term studies with medicine and nursing students. Longitudinal studies are emerging; however, the research within allied health students remains scant. The present study investigates the value of simulation-based learning activities in relation to affective learning among dietetic students.

Methods: A double hermeneutic, interpretative phenomenological approach (IPA) approach was employed, followed by an analysis of the trajectory of participants' affective learning across three-interview time points via the application of Krathwohl's affective learning levels.

Results: The simulation developed affective learning in four of the six participants, specifically in relation to their view of themselves as practitioners and their understanding of their future responsibilities to patient care. Three key themes were identified in the participants: (1) feeling of workforce readiness, (2) valuing lifelong learning and (3) attitudes towards interprofessional teamwork.

Conclusions: This IPA methodology described dietetic students' affective learning development as they transitioned to practice as graduate health professionals. Simulation-based learning is one activity that enhances students' learning in the affective domain and educators should consider its value within their programs

KEYWORDS

dietetics clinical practice, education communicationand education, qualitative study design and analysis

Key points

- Simulation can enhance affective learning among dietetic students.
- The simulation developed affective learning in four of the six participants, specifically in relation to their view of themselves as practitioners and their understanding of their future responsibilities to patient care.
- Three key themes were identified in the participants: (1) feeling of workforce readiness, (2) valuing lifelong learning and (3) attitudes towards interprofessional teamwork.

INTRODUCTION

Affective learning, which focuses on values and attitudes, has long been a key component of health professional education, given the need to work with diverse patient groups in complex situations.[1–3] As one of the three domains of learning, affective learning sits alongside the psychomotor and cognitive domains.[4] Following the initial description of learning levels in the cognitive domain by Benjamin Bloom in 1956, a model for the affective domain was developed by Krathwohl *et al.*[5] in 1964. Affective learning has been categorised in a hierarchy of five levels: *receiving*, *responding*, *valuing*, *organization* and *characterization*.[5]

Affective learning processes, related to emotions, attitudes and motivation, also contribute to the development of cognitive and psychomotor domains.[6] The governing bodies of all health disciplines provide frameworks of competency or entry-level graduate standards. When reviewing these standards, a varying terminology is used to describe affective learning or related attributes in each profession, with no uniformity evident[2,3,6–8] despite the three domains being 'extricably intertwined'.[9,10] In medical education, communication and teamwork have been identified as affective domain skills[3]; however, these cannot be isolated, and other affective aspects of respect, responsibility, duty [7] and professionalism[11] are also at play. Among the few studies in this area with dietetic students to date, affective learning has always been paired with cognitive learning and the studies have not focused on defining each domain separately.[12–14] Aspects of professionalism in dietetics students have been considered difficult to describe[15] and assess with current knowledge tests in relation to competency-based education.[16,17] Despite the widely-recognised importance of the affective learning domain, measuring or assessing its development in health students has received far less study.[6,11,18]

In dietetics education, the literature investigating affective learning is scant. Of the evidence that exists, work integrated learning experiences with associated blog entries support transformative learning through critical reflection where students create new meaning from their experiences.[13] There remains a need for evidence of the affective behaviour changes that occur as students develop into practitioners. Although the literature in student healthcare research has recognised the need to measure[8,19] and assess affective learning[2,3,18] the range of approaches remains varied and mainly focused on the short term, such as during or immediately after the learning.[11,20] Longitudinal studies of affective development over time are beginning to emerge but remain rare.

Teaching and learning approaches to develop affective learning skills

Various teaching techniques are known to enhance affective learning in health professional students. Studies supporting journaling and reflective practice have been documented[1,2,6,19,21] with various assessment criteria having been established to measure the level of affective development.[11,18,22] The development of motivational interviewing skills has been shown to increase health student self-efficacy[23] and communication skills and have been linked to increased professionalism.[18] The immersive nature of simulation-based learning (SBL) offers a safe space for student learning and has been utilised in nursing education to incorporate more depth into affective domain development activities.[2,24] When combined with interprofessional learning (IPL), simulation can be a 'powerful affective teaching' method, combining communication and collaboration amongst health professional students.[18]

We would contend that the development of the affective domain is essential to the demonstration of competence in graduate dietitians internationally.

The question remains, how can affective learning be engendered in dietetic students? At one Australian university, SBL activities are embedded throughout the 4-year undergraduate program, with the majority of SBL completed during the third year of study. These SBL include both uni- and IPL activities and include human simulated patients. (Supplementary Table A2). The present study was conducted to investigate the value of SBL in relation to professionally-focused affective learning among dietetic students. More specifically, the study addressed the research questions: (1) What changes in affective learning are observed in dietetics students as they move from student to graduate practitioner? (2) Can dietetics graduates demonstrate acquisition of affective domain capabilities?

METHODS

The researchers employed a double hermeneutic, interpretative phenomenological approach (IPA) approach, followed by an analysis of the trajectory of participants' affective learning across time via the application of Krathwohl's affective learning levels[5] as previously described by Rogers *et al.*[22] Ethical clearance for this study was obtained (GU2019/009) prior to study commencement.

Participant recruitment

All students ($n = 56$) enrolled in a communication and counselling course of a dietetics program at an Australian university were provided with an overview of the study and invited to participate. Interested participants expressed their willingness to participate via email and were then provided with the study information sheet and interview times were arranged.

Each participant was interviewed on three separate occasions: the first prior to clinical placement, the second

immediately after clinical placement, with the final interview taking place 6 months after graduation. A semi-structured interview schedule, adapted from the work of Smith and Osborn,[25] was pilot tested with PhD students and adjusted following feedback, prior to implementation with participants. All interviews were led by one researcher (MCO), a female dietitian involved in the program. Half of the initial interviews were jointly conducted by one other researcher in the team (GDR or CP). All interviews were recorded and transcribed verbatim. Consent to participate in the study and record each interview was obtained in both written and verbal format at the commencement of the first interview (Supplementary Mat_1).

Statistical analysis

Prior to undertaking any analysis, the relevant researchers met online to reflect and discuss their positioning in regard to the study.[26] The transcripts were then analysed by two investigators (MCO and CP) and a research assistant independent of this study, applying a method adapted from Rogers *et al.*,[22] using NVIVO, version 12 (QSR International). A step-by-step approach to analysis of the transcripts was undertaken based on the work of Smith *et al.*,[27] van Manen *et al.*[28] and Saldaña.[29] We utilised a highlighting method, where transcripts were viewed as section or phrases, rather than line by line. This 'double hermeneutic process' is explained simply as 'the researcher making sense of the participant, who is making sense of x'.[22,27] In this method, the analyst first looks for how the participant has made sense of their learning experience. Then, as a second phase, the analyst seeks to make sense of the participant's sense-making in psychological terms, looking for evidence of affective domain learning that may not have been fully evident to the participant at the time. Rather than frequency analysis, which is the number of times a theme could be counted in the analysis, the resulting emergent themes were identified as phenomenon avoiding hierarchical thinking.[30] In doing so, the analyst aimed to interpret the meaning of the identified phenomenon, or the participants' lived experience.[31] Interpretations were discussed by the researchers until agreement was achieved. To align more closely with true IPA methodology, the findings were reported with interpretations of meaning rather large sections of direct quotes.[32,33]

To answer the first research question and identify evidence of affective learning and changes across time, the researchers reviewed each participant's transcript series against Krathwohl's five levels of affective learning: *receiving*, *responding*, *valuing*, *organization* and *characterization.*[5] To answer the second research question, the emergent themes were reviewed and linked to the affective domain where possible. The method previously described by Rogers *et al.*[22] was employed: (i) identification of examples of affective learning in transcripts, (ii) comparison with the Krathwohl's level of learning[5] and (iii) identifying the highest Krathwohl level of affective learning for which there was evidence in the transcript. To maintain research rigor, the identified themes and associated student quotes were compared and discussed to identify and acknowledge the lens through which each researcher viewed the transcripts. Minor discrepancies in interpretation were resolved by discussion.

RESULTS

Seven female third-year dietetics students initially consented to participate in the sequence of in-depth interviews for the study. Six students completed all three interviews. One did not and was removed from the study. One participated in interview #2 twice as a result of an extension of clinical placement for remedial purposes.

IPA and Krathwohl's levels analysis

The results are presented in two sections. First, evidence of affective learning across the three time-points is reported and tabulated using Krathwohl's five levels of affective learning[5] (Table 1). Second, a summary is provided of the development of the attributes of affective learning across the course of the study evident in the participants and categorised into key themes. Quotes and examples have been linked to participant and interview number using 'P' to indicate the participant ID (01-06) (Table 1), followed by a hyphen (-) and then the interview number (1,2 or 3) (Figure 1).

Affective learning: Evidence of change over time

Four of the six participants demonstrated evidence of *characterization*, the highest level of Krathwohl's affective learning taxonomy.[5] One of these students, demonstrated this during interview #2, whereas the others did so during interview #3. The two who did not reach *characterization* level showed evidence of the *organization* level of affective learning during interview #2 but did not demonstrate further affective development during interview #3.

Attainment and demonstration of the highest level of Krathwohl's affective learning levels was clearly identified for participant 1. During interview #1, participant 1 displayed evidence of *receiving* and *responding* as they transitioned from a simple description and observation of their role within an IPL team to recognising an emotional reaction to them; frequent use of the word 'I' along with a description of their feelings was evident. During interview #2, the participant appeared to demonstrate

TABLE 1 Examples of Krathwohl's affective learning levels achieved for each participant[5]

Participant 1 (P01)	Participant 2 (P02)	Participant 3 (P03)	Participant 4 (P04)	Participant 5 (P05)	Participant 6 (P06)
Receiving: is being aware of or sensitive to the existence of certain ideas, material, or phenomena and being willing to tolerate them *Evidence — the student has at least noticed some aspects of the experience that might ultimately lead to affective learning. For example, a report of something the student found novel or interesting but no discussion of the emotions that the experience has engendered in them*					
(P01-1): You got to see the other professionals, and you got to see what the doctors do, the pharmacists do. It was really good to be able to see your scope of practice in play	**(P02-1):** They didn't know what they were doing in terms of nutrition, and I didn't know what I was doing in terms of medicine. But when we worked together there was no academic difference because we both knew what we were doing on our own paths	**(P03-1):** I thought that was the most lifelike because all the occupations were there. Yeah. Because all the occupations are there you could bounce ideas off each other and other people	**(P04-2):** I like to work on my own but I also like to know that there's a team around me as well.	**(P05-1):** [Simulation has] given me a little insight of what it might be like so that I can interact with other disciplines and be okay talking to other people	**(P06-1):** I was afraid of interacting with the real patient or actor. I was very afraid of it. I was very very nervous … I remember just before I entered [the room] 'he's just a human. Just like the rest of the actors, nobody is going to judge me'
Responding: is committed in some small measure to the ideas, materials, or phenomena involved by actively responding to them *Evidence – the student has reflected on some of the experiences and has identified their own intellectual and, especially emotional reactions to them*					
(P01-1): I just realised I am not as terrible as I thought I might be, or what I'm going to say isn't as incorrect	**(P02-1):** I actually felt like we were important. We felt like we were important and actually achieving something. It wasn't just a simulation and we were just learning. I felt we were all working as a team to treat a real patient	**(P03-1):** Then we went back into the room and that's where the med students started firing questions and I could actually answer them. I was like this is nice! I was thinking they'll know all of that for sure but they didn't. So it was nice to be able to teach them something	**(P04-2):** Nursing staff l found were always quite busy but they would still stop and give you the time	**(P05-1):** I was out of my comfort zone. I didn't have a criteria to meet. That was the learning from me	**(P06-2):** I don't think we just take food but I think like, um maybe the other students look at us and think oh what are you doing? But I do think that they learned from us and what we do, because when we had that debrief all together, they had questions and we were able to teach them things they didn't know. So that was really good
Valuing: is willing to be perceived by others as valuing certain ideas, materials, or phenomena *Evidence – the student has gone beyond just recognition of the personal impact of an experience or appreciation that the experience has enabled them to learn something about themselves as a person that they see as valuable or important*					
(P01-2): I think that I didn't have or didn't value rapport building or those interpersonal skills or active listening I probably wouldn't get very far in patient care	**(P02-2):** I'm a rip the band aide off kind of person. I'd rather just get in, get it done and learn from it after. Learn from the experience afterwards	**(P03-2):** I don't think there was that nervousness or that stress in talking to them [the doctor] and I think it was once you get the first phone call out of the way it was like oh yeah okay I will call you	**(P04-3):** I was probably more surprised by the nurses and how busy they were or appeared to be and yeah just that feeling of them not listening to you	**(P05-2):** Never thought I would be that person and you sort of get to a stage where you've learned so much and then all of a sudden I feel like there's no more brain space left, how am I going to continue to learn and keep going but	**(P06-4):** I learned that I need to be myself and need to be honest with everything I do. But I don't need to share all my emotions. I just need to choose and pick

(Continues)

TABLE 1 (Continued)

Participant 1 (P01)	Participant 2 (P02)	Participant 3 (P03)	Participant 4 (P04)	Participant 5 (P05)	Participant 6 (P06)
		when I need something and that worked well		that's the stress and letting yourself get into your head and contemplate everything and start second guessing. And it's that spiral effect. For me that was a big learning curve, identifying my stresses because I thought I had that under wraps. And it's that spiral effect	and show the emotions that I need to show and the emotions that that patient would accept
***Organization*:** is to relate the value to those already held and bring it into a harmonious and internally consistent philosophy *Evidence – the experiences have had a significant impact on the student's value system or world view in relation to an aspect of future practice*					
(P01-2): It's in those moments where you realise you can know it all and have all the skills but if you can't show empathy and if you can't be just a human being and take off the white coat so to speak, um anything you say after that moment where you don't demonstrate empathy, or good rapport building is kind of out the window. You've lost the patient and that's a shame	**(P02-3):** The reflections may seem like a pain at the time because they are small assessments and they take time but overall they are teaching you to be a reflective person which is really important for improving yourself professionally and personally	**(P03-3):** Initially I got in the habit of being like I'm a new graduate dietitian, and then I'm like no shut up don't tell people you're a new grad dietitian, just tell them you're a dietitian and then they're not even going to blink about the fact that you might be new	**(P04-3):** I expect them to be approachable, and I don't know and nice and friendly and open to a new dietitian coming in	**(P05-3):** When you're talking to your patient one of the big things I got from placement was that food and drink is like their one thing they enjoy and they can have a an opinion on and going into talk to them in a hospital they sort of don't mind talking to dietitians in hospital. It brings a little bit of quality of life to their stay and it's not always bad news, so I feel like I'm the one practitioner they don't mind seeing. So, I was a big advocate for the patient so not for us as dietitians necessarily but having the opportunity to make them feel a little bit better	**(P06-4):** Just trying to give them the best service that you can, and best communication and try to build the best rapport you can and it's up to them if they want to take it, or if they want to leave it

TABLE 1 (Continued)

Participant 1 (P01)	Participant 2 (P02)	Participant 3 (P03)	Participant 4 (P04)	Participant 5 (P05)	Participant 6 (P06)
***Characterization*:** is to act consistently in accordance with the values he or she has internalised *Evidence – the student's value system in relation to an important area of practice has changed or is in the process of changing their professional behavior*					
(P01-2): But if you understand that everything is transferable I think you would invest more of your heart into it	NA	**(P03-3):** I went from like oh everyone, placement is lovely because everyone is equal and everyone is happy to answer each other's questions and everyone has time for everyone to then like oh no, back out and it's not actually like that and some people think they're more important than others	NA	**(P05-3):** I think the sink or swim is what starts and then that gives me the confidence to just go for it and just do it but then once I'm in the swing of things and constantly repeating then that's where I improve and where I grow and get better at what I'm doing	**(P06-4):** All these challenges turn me out to the person that I am. So my wisdom to them is if you're challenged, just take it on because in the end that will make you a better dietitian
This participant had highly developed sense of role and identity due to prior experience in the field, so it appears that affective learning occurred much earlier than for others	This participant was not working in the field of dietetics, not by choice, so was unable to move past the negative experiences encountered during placement. It was difficult to deeply discuss topics that might allude to affective learning attributes	This participant appeared overly confident in their own skills from Int 1 prior to placement. The interviews did not clearly demonstrate affective learning. Perhaps the participant has not yet faced challenges or situations where a transformation in learning occurred	There is evidence that this participant now has clear expectations as to how an interprofessional team should operate; open, friendly, listening. Although not a change in their own practice, the views of others and their role in the medical team have been determined by the participant	This participant discusses their own learning journey in regards to their own skill development. They progress to considering learning as whole, not just individual skills. Lifelong learning here demonstrates affective development	This participant completed four interviews, due to a remedial placement. Int 4 was conducted post graduation and suggests a reflective practitioner, no longer worried about failing or nervousness. The tone suggested a practitioner ready to continue their learning journey to provide better patient care

Note: Three interviews were conducted and are indicated as Int 1 (interview #1: prior to practical clinical placement), Int 2 (Interview #2: immediately after practical clinical placement) and Int 3 (Interview #3: 6 months after graduation from the Dietetics Program). Participant 6 completed an additional interview: Int4.

Abbreviation: NA, not available.

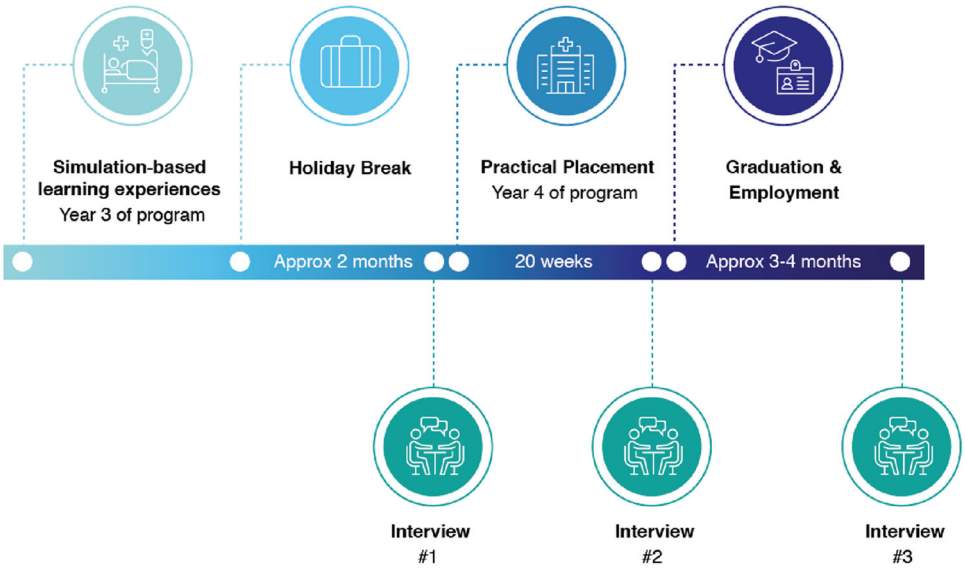

FIGURE 1 Visual representation of interview timeline in relation to simulation activity within program of study, placement, graduation and employment

progression through the next three levels of *valuing*, *organization* and *characterization* as she described the personal impact of the IPL experience and 'rapport building' and reflected on why it was valuable to her. In demonstrating *organization*, the participant shifted from a focus on self to a broader worldview where she values 'empathy' rather than her intellectual ability, as in *receiving*. A key characteristic of *characterization* is a sense of consolidation of affective learning, where planned behaviour is evident. This participant spoke of 'transferrable skills', which represents a profound shift from interview #1 where the observation of skills required and the need to possess a specific skill set was of high importance to her.

Conversely, participant 4 did not demonstrate the same progression of affective learning as participant 1. She moved from lower levels of *receiving* and *responding* in interview #2, where she described experiences that might lead to affective learning but stopped short linking these to personal and impactful examples. Following her practical placement experience, this participant provided evidence that the IPL experiences had a significant impact on her value system when she described her expectation of nurses' and doctors' approach to dietitians in the workplace. However, this participant stopped short of *characterization*, with no foreshadowing of a change to her practice or a planned changed to professional behaviour.

There did not appear to be a link between having worked as a dietitian since graduation and the achievement of *characterization* level. For example, P01 at interview #3 was still looking for work as a dietitian yet demonstrated a value system that was congruent with that of the profession. She had moved beyond a focus on the need for skill development and repetition toward recognising the role of feedback in learning, rather than feedback as criticism; 'feedback … as if it is a reflection on them personally instead of their practice …' (P01-3). On the other hand, P04 who was working as a dietitian at the time of interview #3 did not yet show a change in her principles or ideals regarding professional behaviour. This is not to say that the participant was unprofessional, but rather that there was no evidence of a change of her self-perceived roles and responsibilities as a practitioner. There was evidence of *organization* level affective learning in P04 where patient care was acknowledged as the most important aspect of practice, but the participant was yet to link this to an over-arching sense of her responsibility as a clinician in a healthcare system. P04 reflected on her patient-centred care focus during university SBL conducted prior to clinical practice, compared to the sense of responsibility to the patient she felt after graduation:

> 'I just know when I saw the patient … and I had to give the … I didn't do it very well because I didn't really know what I was talking about so I was just saying words without actually portraying what I wanted to say, with care' (P04-3)

The shift from concentration on themselves towards a patient-centered focus demonstrated the development of affective learning over time. Prior to practical placement, participants spoke of lectures, theory and their own feelings of their skill level, 'it really allowed you to see how much of yourself you could bring to the table' (P01-1). Six months later, after 20 weeks of practical placement, a metaphor of a 'bridge' was used to describe feelings linking university learning with practical experiences:

'you think about the expectations of the supervisors … and then you think about what university has taught you and then you've got to make a bridge' (P01-2). Finally, a genuine shift from a focus on self to their impact on the patient, away from individual and personal learning experiences, was evident: 'Someone's condition in front of you. Someone's emotions in front of you. It's all just very different. It's not just textbook stuff' (P01-3) (Table 2).

Affective learning: Key themes identified in dietetics students and graduates

Three key themes were identified within the affective learning in the participants: (1) feeling of workforce readiness, (2) valuing lifelong learning and (3) attitudes towards IPL teamwork.

Theme 1: Feeling of workforce readiness

The participants appeared to be shaping and developing their own views of themselves as practitioners during the final interview especially. All described a sense of confidence enabling them to feel ready to practice. No longer needing to 'seek approval' to complete tasks was described by P02 following practical placement, the participants developed a sense of their own resilience, evident in the final interview where they were 'accepting that things aren't always going to go amazing' (P02-3).

All participants described strong feelings of being 'practice ready' during their third and final interview. 'This is my practice. This is what I'm bringing' (P05-3). They no longer viewed themselves as a novice student, but rather as an independent practitioner. This was evident with one student feeling like they were 'the blind leading the blind' prior to practical placement, then feeling that their opinion was valued in the clinical setting, to a lifting of the 'student mentality' (P02-3).

Theme 2: Valuing lifelong learning

Prior to practical placements, participants reported feeling 'ready' and 'confident' to embark on the 20-week learning journey, despite some misgivings; 'I just hope that I have got that knowledge stored and that I can apply it' (P05-1). In the final interviews, participants reflected on their placement journey, recalling positive and negative experiences. Over time, students changed from the view that placement was discrete (beginning and end) to the realisation that a formal learning endpoint was never going to emerge. Participants then appeared to acknowledge and value lifelong long learning; 'if you're perfect from day one, then you would not need to be learning' (P03-3).

Theme 3: Attitudes towards interprofessional teamwork

Learning 'with, from and about'[34] colleagues in other professions commenced during the simulation experiences at university and continued throughout practical placement. The 'about' aspects were particularly evident in the participant stories as they became more aware of the role and contribution other disciplines made to patient care. Equally important was the learning that took place about their own role as a dietitian and a newfound insight 'of what it might be like so that I can interact with other disciplines' (P05-1).

Participants were seen to progress from learning *with*, to learning *from* other disciplines[34] in the clinical setting. 'I learned a lot from their approach to each patient' (P05-3). Participants moved from assessment of the patient through their own eyes, to an understanding of how others interact with the patient, communicate, and undertake tasks. In the *characterization* stage, there was evidence of the team approach developing where participants describe their ability to 'bounce ideas' when 'the multidisciplinary team works together' (P03-3). They reflected on the importance of a developed understanding of each other's role and 'knowing how you all interact together' (P05-3).

The participants also reflected on negative IPL encounters particularly relating to the perception of the doctor–dietitian hierarchy. The IPL simulations at university appeared to break some preconceived ideas some participants held about doctors:

> 'We just have this mentality that doctors run hospitals. But they know everything and that everyone else is just underneath them but no, it's nothing like that' (P03-1)

These feelings were confirmed during practical placement as the doctors were considered 'just normal people' (P03-2). An interesting change occurred as the participants moved into the workforce. There was a newfound ability to distinguish between the profession and the person. The participants no longer spoke globally about a discipline or role, rather they looked beyond the title and saw the other practitioner as a person, acknowledging that the person may have their own beliefs that are not representative of a whole profession; 'some people think they're more important than others' (P03-3).

DISCUSSION

To our knowledge, this is the first longitudinal study of affective learning in dietetic students and graduates. Using a double hermeneutic IPA approach, the present study demonstrated the development of the affective learning domain as dietetic students transitioned into practicing health professionals. Comparison of the

TABLE 2 Examples of participant responses showing linked themes and changes across three time points

Question Area	Interview 1	Interview 2	Interview 3
Past experience of simulation learning			
Examples from interview series	*Interviewer*: You describe CLEIMS as being the deep end, can you explain why you say that? *P05*: It sort of helped me rely on my knowledge and feel a bit more confident that I do know things that I can just do the stuff	*Interviewer* (responding to P05 comment): At the time you remember thinking this is like CLEIMS? *P05*: we were more confident and we were able to step out from the background and say oh dietitian over here I want to put my 2 cents in… So a similar situation but [I was] a lot more confident	*Interviewer*: Can you think about a time in 3rd year when you felt confident and thought oh yes this practice is helping me? *P05*: CLEIMS again, that was my really big turning point where I felt – cause I sort of had to jump in because my partner got a bit nervous and I had to jump in and do it … And that was my turning point when I went yeah I can do this, I've got this
Learning outcomes			
Examples from interview series	*Interviewer*: Can you think about the courses that you were doing … which of the activities relate to the simulation activities you've listed here *P02*: By the end of it he [the actor] was like fine. It was, I think I use the communication and counselling course really well in that sim. He started off up here and angry any calm down. By the end of it he left on good terms, with at least me. I think that was a really good example of me using my course work	*Interviewer*: And when in placement did that happen? *P02*: so I sat down with my supervisor… I'm a rip the band aide off kind of person. I'd rather just get in, get it done and learn from it after. Learn from the experience afterwards	*Interviewer*: were there other simulations where you walked away and something happened where it really encouraged and boosted your confidence? … so it was the self-reflection after the fact plus some feedback? *P02*: the reflections may seem like a pain at the time because they are small assessments and they take time but overall they are teaching you to be a reflective person which is really important for improving yourself professionally and personally
Impact on future			
Examples from interview series	*Interviewer*: So take the example of the speech pathologist. Can you tell me the story about when you met the speech pathologist and what happened? *P04*: That would have been actually during CLEIMS. But the first time yeah I didn't, I had no idea that we would be working together on the chart or working with their food with regard to the puree and all of that. I didn't know that we would work together that closely	*Interviewer*: [you enjoy working as part of a team]. Why is that? *P04*: I think learning what they did and seeing how the difference they make and then how it all intertwines, especially the speechies I guess cause they would sit with the children and do the what can they eat and then talk to me about what they can eat and can't eat. *Interviewer*: How did that affect your job as a dietitian? *P04*: It was better … I like to work on my own but I also like to know that there's a team around me as well	*Interviewer*: why is that at the forefront of your brain? *P04*: you're always working with all the other disciplines so it was a bit more beneficial knowing how you all interact together
Summary			
Examples from interview series	*Interviewer*: to summarise in a few words how would you describe your simulation experience to the next third year cohort coming through what would you say? *P03*: it was probably just as, if not more beneficial than sitting in class and finishing off assignments	*Interviewer*: Do you think that you have some advice for our 3rd years that are about to embark on [next trimester]? *P03*: Honestly I reckon I remember that stuff [simulations] more than my assignments	*Interviewer*: If you had to describe the simulation experience, your words of wisdom for 3rd years, what would you say about the simulation experience? *P03*: even though it doesn't have that assessment attached to it, probably put in a bit more focus

Note: Interprofessional students provide medical care to an actor patient as part of a week-long simulation.
Abbreviation: CLEIMS, Clinical Learning through Extended Immersion in Medical Simulation.

affective learning identified with Krathwohl's hierarchical levels[5] enabled participants' affective learning trajectories to be seen over time. The IPA approach also identified key themes within the development of affective learning that are consistent with the capabilities required of graduate dietitians. These findings can inform the development and refinement of innovative teaching methodologies such as SBL to enhance the affective development of dietetic students.

The inclusion of SBL within health professional education programs has been shown to have positive impacts on affective development in medicine[22] and nursing,[23,35] as well as more broadly.[18] The present study has demonstrated the link between human–patient SBL in dietetic undergraduate education and affective learning, specifically in relation to their view of themselves as practitioners and their understanding of their future responsibilities to patient care. The theme surrounding workforce readiness was directly attributed to the IPL simulations undertaken in year 3 of the program during both the second and third interviews in the present study. The participants described 'light bulb' moments where they were able to recall the specific experiences during practical placement that resembled the IPL simulation the year prior, and the profound impact that the activity had had on their practice. After graduation, similar stories were recalled by participants, suggesting a lasting impact of these activities on their learning and practice. There was evidence of a shift in their value systems towards 'professional responsibility, interprofessionalism and the primacy of patient or client welfare', which mirrors the findings in the work of Rogers *et al.*[22] among medical students. Similarly, the dietetic literature provides evidence of the impact of SBL on placement and workforce readiness. SBL in coursework that mimics the work of a dietitian supports preparation for placement[36] and enhances their preparedness for placement.[37] Affective learning should be fundamental to all learning objectives in curriculum and SBL included because it can shape affective development.[18]

The present study poses further questions about the assessment of the affective domain in health professional students. The literature indicates common methods of evaluating affective attributes, including self-reporting questionnaires and Likert scales,[20] to the formative assessment of professional role development,[2] to summative assessments required to determine competence in this domain.[3] These summative assessments, usually undertaken by a preceptor or supervisor to assess professionalism, are reported as uncomfortable because of their subjectivity.[17] The challenge is therefore to develop a robust tool for assessing affective development that has been trialled and validated and for which assessors have been trained. The present study has identified one possible method for assessing affective learning development using a hierarchical system, althoughg further testing is still required.

This small-but-deep longitudinal study has successfully applied an IPA methodology to describe dietetic students' affective learning development as they transition to practice as graduate health professionals. Larger scale studies will be needed to test this proposed methodology further and advance our understanding of the development of affective learning in health professional education over the course of students' study programs and into the workforce. Educators should consider embedding activities that enhance students' learning in the affective domain at the same time as planning to assess their capability in this complex area, which is vital to patient-centred care.

ACKNOWLEDGEMENTS

We acknowledge the contribution of Mari Somerville, Dietitian and PhD Candidate at Griffith University, for transcription and analysis assistance, as well as Joe-Anne Kek-Pamenter for her creative interpretation of the data in this study. No funding was received for this study. Open access publishing facilitated by Griffith University, as part of the Wiley - Griffith University agreement via the Council of Australian University Librarians.

CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

AUTHOR CONTRIBUTIONS

Marie-Claire O'Shea conducted the studies as part of doctoral research under the supervision of the other authors. Marie-Claire O'Shea wrote the first draft and all authors contributed to subsequent drafts of the manuscript.

ETHICAL STATEMENT

Ethical clearance for this study was obtained from Griffith University (GU2019/009) prior to study commencement.

TRANSPARENCY DECLARATION

The lead author affirms that this manuscript is an honest, accurate and transparent account of the study being reported. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned have been explained.

ORCID

Marie-Claire O'Shea https://orcid.org/0000-0001-8226-7910
Claire Palermo https://orcid.org/0000-0002-9423-5067
Gary D. Rogers https://orcid.org/0000-0003-4655-0131
Lauren T. Williams https://orcid.org/0000-0002-7860-0319

REFERENCES

1. Muzyk AJ, Lentz K, Green C, Fuller S, Byron May D, Roukema L. Emphasizing Bloom's affective domain to reduce pharmacy students' stigmatizing attitudes. Am J Pharm Educ. 2017;81(2):35.
2. Krause SA. Precepting challenge: helping the student attain the affective skills of a good midwife. J Midwifery Womens Health. 2016;61(S1):37–46.

3. ten Cate TJ, De Haes JCJM. Summative assessment of medical students in the affective domain. Med Teach 2000;22(1):40–3.
4. Bloom BS. Taxonomy of educational objectives: the classification of educational goals. In: Handbook 1-2. New York: Longmans: McKay; 1956.
5. Krathwohl DR, Bloom BS, Masia BBC. Handbook II: affective domain. New York: David McKay Company; 1964.
6. Pagatpatan CP, Valdezco JAT, Lauron JDC. Teaching the affective domain in community-based medical education: a scoping review. Med Teach. 2020;42(5):507–14.
7. Mann KV, Ruedy J, Millar N, Andreou P. Achievement of non-cognitive goals of undergraduate medical education: perceptions of medical students, residents, faculty and other health professionals. Med Educ. 2005;39(1):40–8.
8. Stupans I, Scutter S, Sawyer T. Fostering professionalism through scaffolding in first year clinical placements. Innov Educ Teach Int. 2011;48(3):263–74.
9. Findley WG, Woodruff AD. Taxonomy of educational objectives, handbook II: affective domain by D. R. Krathwohl, B. S. Bloom, and B. B. Masia. J Educ Measure. 1964;1(2):169–76.
10. Bamidis PD. Affective learning: principles, technologies, practice. In Frasson C, Kostopoulos G, eds., Brain function assessment in learning. Cham: Springer International Publishing; 2017. p. 1–13.
11. Rogers GD, Mey A, Chan PC, Lombard M, Miller F. Development and validation of the Griffith University Affective Learning Scale (GUALS): a tool for assessing affective learning in health professional students' reflective journals. MedEdPublish. 2018;7(1):1–10.
12. Silagyi-Rebovich J, Brooks G, Peterson E. Efficacy of an assessment instrument to measure affective and cognitive learning domains of students enrolled in food or nutrition courses. J Hum Nutr Diet. 1998;11(6):519–27.
13. Shafer KJ, Knous BL. A longitudinal study of cognitive and affective behavior in a didactic program in dietetics: implications for dietetics education. J Acad Nutr Diet. 2001;101(9):1051.
14. Wright L, Lundy M. Blogging as a tool to promote reflection among dietetic and physical therapy students during a multidisciplinary international service-learning experience. J Allied Health. 2012;41(3):73E–8E.
15. Dart J, McCall L, Ash S, Blair M, Twohig C, Palermo C. Toward a global definition of professionalism for nutrition and dietetics education: a systematic review of the literature. J Acad Nutr Diet. 2019;119(6):957–71.
16. Ash S, Palermo C, Gallegos D. The contested space: the impact of competency-based education and accreditation on dietetic practice in Australia. Nutr Diet. 2019;76(1):38–46.
17. Palermo C, Gibson S, Dart J, Whelan K, Hay M. Programmatic assessment of competence in dietetics: a new frontier. J Acad Nutr Diet. 2016;117(2):175–9.
18. Donlan P. Developing affective domain learning in health professions education. J Allied Health. 2018;47(4):289–95.
19. Goldie J, Dowie A, Cotton P, Morrison J. Teaching professionalism in the early years of a medical curriculum: a qualitative study. Med Educ. 2007;41(6):610–7.
20. Buissink-Smith N, Mann S, Shephard K. How do we measure affective learning in higher education? J Educ Sustain Dev. 2011;5(1):101–14.
21. Chauvin SW. Professionalism: a shared responsibility for a rich and enduring tapestry. Med Educ. 2002;36(5):410–1.
22. Rogers GD, Mey A, Chan PC. Development of a phenomenologically derived method to assess affective learning in student journals following impactive educational experiences. Med Teach. 2017;39(12):1250–60.
23. Oh P-J, Jeon KD, Koh MS. The effects of simulation-based learning using standardized patients in nursing students: a meta-analysis. Nurse Educ Today. 2015;35(5):e6–e15.
24. Andrusyszyn MA. Clinical evaluation of the affective domain. Nurse Educ Today. 1989;9(2):75–81.
25. Smith JA, Osborn M. Interpretative phenomenological analysis. In: Smith JA editor. Qualitative psychology: a practical guide to research methods. SAGE; 2008. p. 53–79.
26. Hopkins RM, Regehr G, Pratt DD. A framework for negotiating positionality in phenomenological research. Med Teach. 2017;39(1):20–5.
27. Smith JA, Flowers P, Larkin MH. Interpretative phenomenological analysis: theory, method and research. London: SAGE; 2009.
28. van Manen M. In: Smith PL editor. Researching lived experience: human science for an action sensitive pedagogy. Canada: State University of New York Press; 1990.
29. Saldaña J. The coding manual for qualitative researchers. Los Angelos: SAGE; 2016.
30. Crowther S, Thomson G. From description to interpretive leap: using philosophical notions to unpack and surface meaning in hermeneutic phenomenology research. Int J Qual Methods. 2020;19:1609406920969264.
31. Sloan A, Bowe B. Phenomenology and hermeneutic phenomenology: the philosophy, the methodologies, and using hermeneutic phenomenology to investigate lecturers' experiences of curriculum design. Qual Quant. 2014;48(3):1291–303.
32. Dahlberg H, Dahlberg K. The question of meaning—a momentous issue for qualitative research. null. 2019;14(1):1598723.
33. Norlyk A, Harder I. What makes a phenomenological study phenomenological? An analysis of peer-reviewed empirical nursing studies. Qual Health Res. 2010;20(3):420–31.
34. Goldman J. Centre for the Advancement of Interprofessional Education (CAIPE) website: www.caipe.org.uk. J Interprof Care. 2011;25(5):386–7.
35. Chang YP, Cassalia J, Warunek M, Scherer Y. Motivational interviewing training with standardized patient simulation for prescription opioid abuse among older adults. Perspect Psychiatr Care. 2019;55(4):681–9.
36. Palermo C, Dart J, Begley A, Beck EJ, Bacon R, Tweedie J, et al. Dietetics students' construction of competence through assessment and placement experiences. Nutr diet. 2018;75(3):307–15.
37. Morgan K, Campbell KL, Sargeant S, Reidlinger DP. Preparedness for advancing future health: a national qualitative exploration of dietetics graduates' experiences. Adv Health sci Educ Theory Pract. 2020;25(1):31–53.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: O'Shea M-C, Palermo C, Rogers GD, Williams LT. Development of affective learning in dietetics graduates: A qualitative longitudinal study. J Hum Nutr Diet. 2022;35:872–882. https://doi.org/10.1111/jhn.12993

Received: 1 November 2021 | Accepted: 22 February 2022

DOI: 10.1111/jhn.13004

JHND Journal of Human Nutrition and Dietetics | BDA The Association of UK Dietitians

Undertaking a research project improves confidence in research skills among student dietitians

Kevin Whelan[1] | **Kate R. Castelli**[1] | **Camilla Trizio**[1] | **Oliver Howard**[1] | **Jane E. Thomas**[1] | **Angela M. Madden**[2]

[1]Department of Nutritional Sciences, King's College London, London, UK

[2]School of Life & Medical Sciences, University of Hertfordshire, Hatfield, UK

Correspondence

Kevin Whelan, Department of Nutritional Sciences, King's College London, 150 Stamford St, London SE1 9NH, UK.
Email: kevin.whelan@kcl.ac.uk

Abstract

Background: Research is a cornerstone of evidence-based dietetic practice. Research skills are often taught at university through experiential learning during a final-year research project. The present study aimed to investigate attitudes towards research and confidence in research skills among student dietitians before and after a research project.

Methods: A questionnaire survey of student dietitians' attitudes to research and confidence in research skills was undertaken before and after completing a research project at two universities in London, UK. Dichotomous data were compared before and after the research project using a McNemar's test. Factors associated with 'high confidence' or 'improved confidence' in overall research skills at the end of the research project were investigated using multivariable logistic regression.

Results: In total, 160 student dietitians completed a questionnaire before and after their research project. The majority had positive attitudes to research both before and after their research project. There was an increase in numbers with 'high confidence' in overall research skills before (13; 8.1%) and after (79; 49.4%) the research project ($p < 0.001$), and 113 (70.6%) reported 'improved confidence' in overall research skills. The only factor associated with 'high confidence' in overall research skills was having 'high levels of involvement in the overall research process' (odds ratio = 6.13, 95% confidence interval = 2.03–18.49, $p = 0.001$).

Conclusions: Student dietitians have positive attitudes towards research and undertaking a research project significantly improves confidence in their research skills. A higher level of involvement in the research project is the single most significant factor associated with high confidence in research skills.

KEYWORDS

dietetics, dietitian, education, research, student

Key points

- This is the largest study to date of student dietitians' experiences of undertaking a research project during their university degree.
- Student dietitians have positive attitudes to research both before and after their research project.
- Research projects improve student dietitians' confidence in their research skills.

- The single most significant factor associated with developing high confidence in research skills is having a greater level of involvement in the project.

INTRODUCTION

Research is a cornerstone of evidence-based dietetic practice. Research is essential to provide the evidence for diet–disease relationships, for the effectiveness of interventions and to provide evidence of the impact of dietitians.[1] Research builds a knowledge base for the relatively new discipline of nutrition. It is crucial for the advancement of the dietetic profession[2,3] and for the credibility and public perception of dietitians.[4] Meanwhile, healthcare professionals' involvement in research in the clinical setting can benefit clinical practice, including improvements in health services performance, processes of care and patient outcomes, as a result of having greater knowledge of research studies, implementation of guidelines, and greater networks and collaborative working.[5]

Professional associations or governing bodies have standards for dietitians that include competency in research and evidence-based practice in Australia,[6] Canada,[7] UK,[8] USA[9] and many other countries across the world, and are also included in the International Practitioner Competency Standards for Dietitians set by the International Confederation of Dietetic Associations.[10]

In the wider healthcare professions, generally positive attitudes towards involvement in research have been reported.[11,12] This is also true in small studies of dietitians[13,14] and student dietitians.[15,16] However, there remains a significant gap in healthcare professionals' attitudes to research and their actual participation in research.[17,18] Studies report variable levels of research involvement among dietitians in Australia,[19] Canada,[20] UK[14] and USA.[1,21–23]

Barriers to research involvement in dietetics have been extensively examined and consistently report a lack of time and lack of funding as key issues, but negative attitudes towards research and lack of confidence in research skills have also been identified as important obstacles to research involvement.[21,22,24] In particular, limited pre-registration training in research was reported as a barrier to dietitians subsequently undertaking research in a survey of the Academy of Nutrition and Dietetics,[22] and is consistent with other studies in the USA[1,21,25] and UK.[14]

The reported lack of sufficient research training in pre-registration dietetics programmes coupled with evidence that education, knowledge and interest in research are associated with future research involvement among dietitians[23,24] is concerning because today's students will be tomorrow's profession who will be responsible for undertaking, applying and disseminating future research.[26]

In the UK, pre-registration programmes in dietetics require student dietitians to have a 'critical and applied knowledge and understanding of research …' including, amongst others: research ethics and research governance; the principles of scientific enquiry; quantitative and qualitative research design; data management; statistical analysis and interpretation; critical appraisal; and evidence informed practice.[27] At most universities in the UK, research skills training culminates in the student undertaking a research project usually in the final year of the programme. Exposing students to the research process is supported by an educational theory of experiential learning, a model in which learners gain skills and knowledge from direct experience.[28,29]

A small number of studies have demonstrated that student dietitians' exposure to undertaking a research project improves confidence in their research skills.[3,15,30] However, little is known of the change in attitudes and confidence resulting from undertaking a research project, nor the factors associated with optimal outcome, mainly as a result of the lack of before and after analyses and limited cohort sizes.

The present study aimed to investigate attitudes towards research and confidence in research skills among student dietitians before and after a research project. Specifically, the study investigates: (i) attitudes towards research and confidence in research skills among student dietitians; (ii) the effect of undertaking a final year research project on these attitudes and confidence; and (iii) the factors associated with 'high confidence' and 'improved confidence' in overall research skills.

METHODS

The study used a questionnaire to investigate the confidence and attitudes of student dietitians before and after undertaking their final-year research project.

Participants

Data were collected from students before and after completing a compulsory research project module in their final year of the 4-year BSc Nutrition and Dietetics programmes at King's College London and London Metropolitan University, two large universities in London, UK. All students undertaking the research project module were eligible, with no exclusion criteria, and all

were approached over five consecutive years at King's College London (academic years ending in 2005–2009) and three consecutive years at London Metropolitan University (academic years ending in 2005–2007), aiming to recruit a sufficiently large, unselected and representative sample.

Intervention

Both universities provide students with a compulsory 'research methods' module earlier in the BSc degree (Years 1 or 2) in preparation for the research project module in the final (Year 4). The research project modules involve some research methods teaching (e.g., study design, research ethics, data analysis) followed by undertaking a research project part-time and under supervision for 3–4 months.

Project selection consisted of compilation of a list of research projects proposed by academic staff at the university or by an external dietitian or nutritionist who would co-supervise a project with an internal academic.[31] Students were provided with the list of proposed projects that included the email address of the supervisor(s) who could be contacted for further information regarding the project if required. Projects were all relevant to nutrition and dietetics and were diverse in the type of research activity (e.g., literature review or systematic review, experimental laboratory, questionnaire survey or dietary survey, clinical audits, clinical trial or feeding study). Some projects involved original data collection, whereas others involved analysing data that had already been collected. Students rated their preferred research project (s) and allocation was based not only primarily upon their expressed preference, but also with a goal to distribute supervisory load between academic staff.

Following project allocation, all research projects were conducted according to standard university procedures. A research team was formed consisting of the student dietitian and one (or more) university academic and, for external collaborative projects, the external dietitian/nutritionist. Each research team had a preliminary meeting to discuss the project, team member responsibilities, supervisory arrangements and the dissemination of results.

On completion of the research projects, students wrote a dissertation and prepared and presented a research presentation or poster or participated in a viva voce in line with the assessment requirements of their university.

Questionnaire

Students were invited to participate in a survey of their attitudes and confidence in their research skills by completing a questionnaire before (first lecture of the module) and after undertaking their final-year research project (following submission of their dissertation and completion of their assessment). The questionnaire was developed by the three members of the research team (KW, JET and AMM) with extensive experience of questionnaire design, psychometric testing and survey conduct. Questionnaire design consisted of performing a literature search to identify previously conducted surveys, where possible, based upon which a bespoke questionnaire was developed. The first iteration of the questionnaire was piloted in 36 students and amendments were made following feedback and discussion, and the data collected from the pilot questionnaire were not included in the current analysis.

Attitudes towards research were measured using a series of nine statements reflecting a range of positive and negative attitudes towards research and were taken directly from a previous questionnaire, which, at the time of the study design, was one of the few studies of dietitians' attitudes towards research.[14] The only amendment was to two statements: 'Clinical research should be led by clinicians', which was clarified to 'Clinical research should be led by clinicians (doctors)' to ensure consistency of interpretation, and 'I don't see research as part of my job', which was changed to 'I don't see research as part of a dietitian's job' to reflect the respondents' status as students. Each statement was rated using a five-point Likert scale ('1, Strongly agree', '5, Strongly disagree'), as in the previous questionnaire.[14] As well as presenting data on the level of agreement with each statement, data were collapsed to show the numbers with positive attitudes depending on the framing of statements. For example, rating 'Agree' or 'Strongly Agree' to a positive statement (e.g., 'Research should be carried out by all dietitians') or 'Disagree' or 'Strongly Disagree' to a negative statement (e.g., 'I don't see research as part of a dietitian's job') were both considered to reflect positive attitudes. Data were also used to calculate the numbers whose attitudes improved between baseline and after completing the project (e.g., whose answers moved in a 'more positive' direction). Attitudes towards future involvement in research were measured on a dichotomous Yes/No scale.

Confidence in research skills was measured for 10 research activities based upon the different stages of research process from a model provided by the National Institute of Health Research at the time (e.g., 'Developing a hypothesis', 'Designing a research protocol', and 'Drawing conclusions from research'). Minor adaptations were made; namely, removing a question on obtaining research funding (which is not usually required as part of university research projects): changing 'Report on the study and disseminate the findings' into two processes 'Writing a research report' and 'Orally presenting research findings' (as both were performed as part of the research project modules and require distinct sets of skills); and, finally, a question regarding

confidence in the 'Overall research process' was added (to encompass overall confidence in research and not just in a specific stage of the research process). Confidence was rated on a five-point Likert scale ('1, Not at all confident', '5, A great deal of confidence'). As well as presenting data on confidence in each of the 10 activities and in the overall research process, data were also collapsed to report those with 'high confidence' ('4, A lot of confidence', '5, A great deal of confidence'). The numbers of students with 'improved confidence' were calculated, defined as increasing in confidence by one or more on the Likert scale between baseline and after completing the project (e.g., changing from '2, A little confidence' to '3, Quite a bit of confidence').

The questionnaire completed at the end of the research project also examined the extent to which students were involved in different aspects of research during their project and their perceptions of whether the project had contributed to the development of their research skills. These two outcomes were measured for the 10 research activities and the overall research process and were rated using the same five-point Likert scale ('1, Not at all', '5, A great deal'). High levels of involvement were defined as the student reporting '4, A lot of involvement' or '5, A great deal of involvement' in the research project.

Ethical considerations

The study received ethical approval from the research ethics committees of both King's College London and London Metropolitan University. Questionnaires were distributed during lectures in sealed envelopes and completed on a voluntary basis. Questionnaires were anonymised using a code such that questionnaires before and after the research project could be paired for analysis but did not contain the students' name or any identifiable details. Questionnaire responses were not linked in any way to student records or academic results and did not contribute or impact in anyway on the assessment of the research project module.

Statistical analysis

Data were only analysed for students who provided a questionnaire at both baseline and following completion of the project, in order that changes in attitudes and confidence could be calculated for all respondents. Descriptive statistics were calculated for the variables of interest and data are presented as *n* (%). Dichotomised data were compared between baseline and after the research project using a McNemar's test.

The two major educational outcomes of interest were having 'high confidence' in overall research skills after the research project (coded as either '4, A lot of confidence', '5, A great deal of confidence' on the questionnaire at the end of the project) and 'improved confidence' in overall research skills between baseline and after the research project (coded as an increase in confidence of one or more on the Likert scale between baseline and end of the research project). These two educational outcomes were explored for related factors using univariable logistic regression. Eight variables were entered into the model relating to personal characteristics (age, gender, university, previous involvement in research) and project-related characteristics (supervision model/location, project type, original data collection, student's reported involvement in the overall research process after the project). Personal factors with a $p < 0.1$ in the univariate logistic regression model together with all project-related characteristics were included in the multivariable logistic regression model.

Data were analysed in SPSS, version 26 (IBM Corp.). $p < 0.05$ was considered statistically significant.

RESULTS

Participant characteristics

Questionnaires were distributed to 196 students, of whom 184 (93.9%) returned a questionnaire at baseline and 166 (84.7%) returned one following completion of the research project. In total, 160 (81.6%) students returned a questionnaire at both time points and are the complete case analysis study population reported here.

The 160 students had a median age of 25.0 years (interquartile range = 10.7) and 149 (93.1%) were female (Table 1). Overall, 115 (71.9%) studied at King's College London and 45 (28.1%) studied at London Metropolitan University. Two-thirds (66.3%) undertook an internal project (based at the university and supervised by a university academic) and one-third (33.7%) undertook an external project (based in a hospital, clinic or other research institute, and supervised by both a university academic and an external dietitian/nutritionist). A wide range of project types were undertaken, including questionnaires or dietary surveys (30.0%), literature reviews or systematic reviews (23.8%) and experimental laboratory projects (18.1%) (Table 1).

Attitudes toward research

The majority of student dietitians' responses to statements reflected positive attitudes towards research at baseline and after completing the project (Table 2). The only exception was 'seeing patients is more important than research'. There were no significant differences in the numbers with positive attitudes between baseline and after the research project, except for 'I find it hard to

TABLE 1 Characteristics of the 160 student dietitians participating in the final year research project study

Characteristics	Data
Age, years, median (interquartile range)	25.0 (10.7)
Gender, *n* (%)	
Female	149 (93.1)
Male	11 (6.9)
University, *n* (%)	
King's College London	115 (71.9)
London Metropolitan University	45 (28.1)
Previous research involvement, *n* (%)	
No	134 (83.8)
Yes	26 (16.2)
Supervision model, *n* (%)	
Internal project and supervisor	106 (66.3)
External project with internal and external supervisor	54 (33.7)
Project type, *n* (%)	
Literature review or systematic review	38 (23.8)
Experimental laboratory	29 (18.1)
Questionnaire or dietary survey	48 (30.0)
Clinical audit	24 (15.0)
Clinical trial or feeding study	21 (13.1)

interpret research', for which there was an increase in number of students who 'disagreed' or 'strongly disagreed' between baseline (44.4%) and after the research project (61.8%, $p < 0.001$). The numbers whose attitudes improved after the research project ranged from 10.6% ('I find it hard to interpret research') to 26.3% ('I don't see research as part of a dietitian's job'). In terms of attitudes towards future involvement in research, after the research project, a very small minority of students (5.6%) said they 'did not want to be involved in audit and research' and the majority (63.1%) said they wanted 'to take part in research with colleagues' (Table 3).

After completing the research project, there were no differences for five of the seven attitude statements regarding future involvement in research. However, there was an increase in the numbers who 'hope to do audit and research', (baseline 35.6% vs. after project 48.8%, $p = 0.01$) and 'hope to do research with colleagues' (baseline 50% vs. after project 63.1%, $p = 0.009$) (Table 3).

Confidence in research skills

The number of students with high confidence ('4, A lot of confidence', '5, A great deal of confidence') in their research skills was very low at baseline, ranging from only 6.9% ('statistical analysis') to 35.6% ('orally presenting research findings') (Table 4). However, after completing the research project, there were significantly greater numbers with high confidence for nine of the 10 research skills. This resulted in the majority of students having high confidence in five of the 10 research skills: 'completing a literature search' (82.5%), 'collecting new data' (52.5%), 'writing a research report' (77.5%), 'drawing conclusions from research' (76.3%) and 'orally presenting research findings' (65.6%).

There was also a significant increase in the numbers with high confidence in the 'overall research process' increasing from 8.1% at baseline to 49.4% after the research project. More than half of the students showed improved confidence in their research skills for nine of the 10 research skills (ranging from 53.1% 'statistical analysis' to 75.6% 'writing a research report'). The exception was 'obtaining research ethics approval' (28.8%).

Involvement in research project and perceptions of role in skill acquisition

The areas of the research project in which the most students had high levels of involvement ('4, A lot of involvement', '5, A great deal of involvement') were 'completing a literature search' (91.3%), 'writing a research report' (95.6%) and 'drawing conclusions from research' (95.0%). The areas where fewest students had high levels of involvement were 'obtaining research ethics approval' (11.3%), 'designing a research protocol' (42.5%) and 'deciding on data collection methods' (38.8%). In total, 133 (83.1%) students reported high levels of involvement in the overall research process (Table 5).

Over three-quarters of students (77.8%) reported that undertaking their research project had contributed 'a lot' or 'a great deal' to the development of their overall research skills (Table 5). The majority reported that the research project had contributed 'a lot' or 'a great deal' to their skills in: 'completing a literature search' (76.9%), 'collecting new data' (55.7%), 'writing a research report' (84.4%), 'drawing conclusions from research' (78.1%) and 'orally presenting research findings' (63.1%).

Factors associated with high confidence and improved confidence

In total, 79 (49.4%) students had high confidence in their overall research skills after the research project, and the odds of this outcome was analysed using logistic regression (Table 6). Following univariable logistic regression, the only statistically significant factors were the project being an 'external collaborative project' (odds ratio [OR] 2.05, 95% confidence interval [CI] 1.05–4.00,

TABLE 2 Comparison of attitudes towards research before and after undertaking a research project among 160 student dietitians

Attitude statement		Level of agreement with statements, *n*(%)					Positive attitude[a]		Improved attitude[b]
		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	*n* (%)	*p* value	*n* (%)
Research should be carried out by all dietitians	Baseline	19 (11.9)	71 (44.4)	41 (25.6)	28 (17.5)	1 (0.6)	90 (56.3)	0.542	34 (21.3)
	After research project	28 (17.5)	67 (41.9)	39 (24.4)	22 (13.8)	4 (2.5)	95 (59.4)		
Research should only be carried out by research dietitians	Baseline	8 (5.0)	16 (10.0)	25 (15.6)	85 (53.1)	26 (16.3)	111 (69.4)	0.760	40 (25.0)
	After research project	0 (0.0)	12 (7.5)	40 (25.0)	79 (49.4)	29 (18.1)	108 (67.5)		
All dietitians should be able to act on research	Baseline	72 (45.0)	75 (46.9)	11 (6.9)	2 (1.3)	0 (0.0)	147 (91.9)	0.424	22 (13.8)
	After research project	81 (50.6)	70 (43.8)	6 (3.8)	2 (1.3)	1 (0.6)	151 (94.4)		
Doing research improves patient care	Baseline	70 (43.8)	71 (44.4)	16 (10.0)	3 (1.9)	0 (0.0)	141 (88.1)	0.327	30 (18.8)
	After research project	67 (41.9)	80 (50.0)	11 (6.9)	1 (0.6)	1 (0.6)	147 (91.9)		
I don't see research as part of a dietitian's job	Baseline	2 (1.3)	7 (4.4)	30 (18.8)	69 (43.1)	52 (32.5)	121 (75.6)	0.651	42 (26.3)
	After research project	2 (1.3)	7 (4.4)	26 (16.3)	78 (48.8)	47 (29.4)	125 (78.1)		
Seeing patients is more important than research	Baseline	3 (1.9)	27 (16.9)	72 (45.0)	49 (30.6)	9 (5.6)	58 (36.3)	0.263	38 (23.8)
	After research project	5 (3.1)	17 (10.6)	71 (44.4)	58 (36.3)	9 (5.6)	67 (41.9)		
Research provides evidence to direct patient care	Baseline	78 (48.8)	66 (41.3)	12 (7.5)	1 (0.6)	3 (1.9)	144 (90.0)	0.115	32 (20.0)
	After research project	70 (43.8)	82 (51.3)	5 (3.1)	2 (1.3)	1 (0.6)	152 (95.0)		
Clinical research should be led by clinicians (doctors)	Baseline	1 (0.6)	6 (3.8)	38 (23.8)	80 (50.0)	35 (21.9)	115 (71.9)	0.575	37 (23.1)
	After research project	0 (0.0)	4 (2.5)	36 (22.5)	83 (51.9)	37 (23.1)	120 (75.0)		
I find it hard to interpret research findings	Baseline	7 (4.3)	38 (23.8)	44 (27.5)	61 (38.1)	10 (6.3)	71 (44.4)	< 0.001	17 (10.6)
	After research project	2 (1.3)	15 (9.4)	44 (27.5)	83 (51.9)	16 (10.0)	99 (61.8)		

[a]Numbers (%) with positive attitudes depending on the framing of statements. For example, positive attitudes were considered to be rating 'Agree' or 'Strongly Agree' to a positive statement (e.g., 'Research should be carried out by all dietitians') or 'Disagree' or 'Strongly Disagree' to a negative statement (e.g., 'I don't see research as part of a dietitian's job'). The *p* value represents comparison of the numbers with positive attitudes at baseline and after research project using McNemar's test

[b]Number (%) whose response improved in favour of a more positive attitude towards research after completing a research project.

TABLE 3 Comparison of attitudes towards future involvement in research before and after undertaking a research project among 160 student dietitians

Attitude statement	Baseline,*n*(%)	After research project,*n*(%)	*p* value
I do not want to be involved in audit or research	14 (8.8)	9 (5.6)	0.359
I expect I would have to be involved in audit activities	65 (40.6)	64 (40.0)	1.000
I want to be involved in developing audit projects	40 (25.0)	52 (32.5)	0.127
I want to take part in research with colleagues	80 (50.0)	101 (63.1)	0.009
I hope to be involved in audit and research projects	57 (35.6)	78 (48.8)	0.01
I want to be more involved in research projects	51 (31.9)	61 (38.1)	0.175
I would consider pursuing a higher degree	55 (34.4)	52 (32.5)	0.735

p value represents comparison of the responses at baseline and after research project using McNemar's test

TABLE 4 Confidence in research skills before and after undertaking a research project among 160 student dietitians

Research activity		Level of confidence in research skills,*n*(%)					High confidence[a]		Improved confidence[b]
		Not at all	A little	Quite a bit	A lot	A great deal	*n* (%)	*p* value	
Developing a hypothesis	Baseline	27 (16.8)	64 (40.0)	47 (29.4)	17 (10.6)	5 (3.1)	22 (13.8)	< 0.001	89 (55.6)
	After research project	10 (6.3)	30 (18.8)	58 (36.3)	45 (28.1)	17 (10.6)	62 (38.8)		
Completing a literature search	Baseline	5 (3.1)	37 (23.1)	62 (38.8)	44 (27.5)	12 (7.5)	56 (35.0)	< 0.001	114 (71.3)
	After research project	1 (0.6)	3 (1.9)	24 (15.0)	72 (45.0)	60 (37.5)	132 (82.5)		
Deciding on data collection methods	Baseline	31 (19.4)	68 (42.5)	44 (27.5)	13 (8.1)	4 (2.5)	17 (10.6)	< 0.001	95 (59.4)
	After research project	10 (6.3)	38 (23.8)	56 (35.0)	39 (24.4)	17 (10.6)	56 (35.0)		
Designing a research protocol	Baseline	31 (19.4)	62 (38.8)	48 (30.0)	15 (9.4)	4 (2.5)	19 (11.9)	< 0.001	90 (56.3)
	After research project	13 (8.1)	39 (24.4)	52 (32.5)	44 (27.5)	12 (7.5)	56 (35.0)		
Obtaining research ethics approval	Baseline	80 (50.0)	52 (32.5)	15 (9.4)	9 (5.6)	4 (2.5)	13 (8.1)	0.124	46 (28.8)
	After research project	81 (50.6)	41 (25.6)	16 (10.0)	15 (9.4)	7 (4.4)	22 (13.8)		
Collecting original data	Baseline	24 (15.0)	64 (40.0)	56 (35.0)	13 (8.1)	3 (1.9)	16 (10.0)	< 0.001	100 (62.5)
	After research project	21 (13.1)	24 (15.0)	31 (19.4)	55 (34.4)	29 (18.1)	84 (52.5)		
Statistical analysis	Baseline	47 (29.4)	63 (39.4)	39 (24.4)	8 (5.0)	3 (1.9)	11 (6.9)	< 0.001	85 (53.1)
	After research project	32 (20.0)	31 (19.4)	51 (31.9)	31 (19.4)	15 (9.4)	46 (28.8)		
Drawing conclusions from research	Baseline	12 (7.5)	44 (27.5)	69 (43.1)	29 (18.1)	6 (3.8)	35 (21.9)	< 0.001	120 (75.0)
	After research project	4 (2.5)	2 (1.3)	32 (20.0)	78 (48.8)	44 (27.5)	122 (76.3)		
Writing a research report	Baseline	9 (5.6)	50 (31.3)	73 (45.6)	25 (15.6)	3 (1.9)	28 (17.5)	< 0.001	121 (75.6)
	After research project	2 (1.3)	5 (3.1)	29 (18.1)	68 (42.5)	56 (35.0)	124 (77.5)		
Orally presenting research findings	Baseline	6 (3.8)	36 (22.5)	61 (38.1)	46 (28.8)	11 (6.9)	57 (35.6)	< 0.001	92 (57.5)
	After research project	6 (3.8)	10 (6.3)	39 (24.4)	55 (34.4)	50 (31.3)	105 (65.6)		
Overall research process	Baseline	15 (9.4)	60 (37.5)	72 (45.0)	10 (6.3)	3 (1.9)	13 (8.1)	< 0.001	113 (70.6)
	After research project	3 (1.9)	9 (5.6)	69 (43.1)	59 (36.9)	20 (12.5)	79 (49.4)		

[a]Numbers (%) with 'High confidence' are those reporting either 'A lot' or 'A great deal' of confidence in their research skills. *p* value represents comparison of the numbers with high confidence at baseline and after research project using McNemar's test

[b]Number (%) with 'improved confidence' defined as increasing in confidence by one or more on the Likert scale between baseline and after completing the project (e.g., changing from '2, A little confidence' to '3, Quite a bit of confidence').

TABLE 5 Level of involvement in aspects of the research project and perception of the extent to which the research project contributed to the development of their research skills among student dietitians

	Level of involvement in this aspect of the research project,*n*(%)					Perception of the extent to which undertaking the research project contributed to the development of their research skills,*n*(%)				
Research activity[a]	**Not at all**	**A little**	**Quite a bit**	**A lot**	**A great deal**	**Not at all**	**A little**	**Quite a bit**	**A lot**	**A great deal**
Developing a hypothesis	33 (20.6)	28 (17.5)	28 (17.5)	26 (16.3)	45 (28.1)	15 (9.4)	35 (21.9)	39 (24.4)	48 (30.0)	23[14]
Completing a literature search	1 (0.6)	1 (0.6)	14 (8.8)	31 (19.4)	113 (70.6)	2 (1.3)	8 (5.0)	27 (16.9)	56 (35.0)	67 (41.9)
Deciding on data collection methods	47 (29.4)	28 (17.5)	23 (14.4)	22 (13.8)	40 (25.0)	19 (11.9)	32 (20.0)	44 (27.5)	45 (28.1)	20 (12.5)
Designing a research protocol	41 (25.6)	33 (20.6)	18 (11.3)	27 (16.9)	41 (25.6)	20 (12.5)	33 (20.6)	40 (25.0)	42 (26.3)	25 (15.6)
Obtaining research ethics approval	125 (78.1)	8 (5.0)	9 (5.6)	8 (5.0)	10 (6.3)	100 (62.5)	29 (18.1)	13 (8.1)	8 (5.0)	10 (6.3)
Collecting original data	43 (26.9)	9 (5.6)	18 (11.3)	15 (9.4)	75 (46.9)	31 (19.4)	19 (11.9)	21 (13.1)	51 (31.9)	38 (23.8)
Statistical analysis	36 (22.5)	15 (9.4)	19 (11.9)	23 (14.4)	67 (41.9)	31 (19.4)	25 (15.6)	40 (25.0)	36 (22.5)	28 (17.5)
Drawing conclusions from research	3 (1.9)	1 (0.6)	4 (2.5)	29 (18.1)	123 (76.9)	5 (3.1)	4 (2.5)	26 (16.3)	68 (42.5)	57 (35.6)
Writing a research report	4 (2.5)	1 (0.6)	2 (1.3)	14 (8.8)	139 (86.9)	5 (3.1)	4 (2.5)	16 (10.0)	57 (35.6)	78 (48.8)
Orally presenting research findings	11 (6.9)	10 (6.3)	5 (3.1)	16 (10.0)	118 (73.8)	9 (5.6)	18 (11.3)	32 (20.0)	52 (32.5)	49 (30.6)
Overall research process[a]	5 (3.1)	2 (1.3)	20 (12.5)	38 (23.8)	95 (59.4)	0 (0.0)	3 (2.6)	23 (19.7)	49 (41.9)	42 (35.9)

[a]Data are from 160 student dietitians, except for perceptions of the extent to which undertaking the research project contributed to the development of their research skills in the 'overall research process', which is from 117 students as this question was only introduced from the second cohort onwards.

TABLE 6 Univariable and multivariable analysis of participant and project-related factors associated with having 'high confidence in overall research skills' and having 'improved confidence in overall research skills' after completing the research project among 160 student dietitians

	High confidence in overall research skills after project[a]				Improved confidence in overall research skills after project[b]			
	Univariable analysis		Multivariable analysis		Univariable analysis		Multivariable analysis	
Variable (reference group)	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age	0.98 (0.93–1.02)	0.284	–	–	0.96 (0.91–1.00)	0.071	0.97 (0.92–1.02)	0.245
Gender (Female)								
Male	1.25 (0.37–4.27)	0.723	–	–	0.47 (0.14–1.63)	0.234	–	–
University (London Metropolitan)								
King's College London	1.16 (0.50–2.32)	0.668	–	–	**2.27 (1.10–4.71)**	**0.027**	1.81 (0.73–4.51)	0.202
Previous research involvement (None)								
Some previous research involvement	1.80 (0.76–4.26)	0.179	-	-	0.92 (0.37–2.30)	0.865	-	-
Supervision model/location (Internal)								
External project	**2.05 (1.05–4.00)**	**0.035**	2.11 (0.81–5.47)	0.126	1.49 (0.71–3.14)	0.295	0.98 (0.33–2.89)	0.969
Project type (Literature review)								
Experimental laboratory	1.25 (0.47–3.32)	0.660	2.26 (0.51–10.10)	0.285	2.54 (0.88–7.37)	0.085	1.92 (0.36–10.39)	0.448
Questionnaire or dietary survey	1.67 (0.70–3.95)	0.246	1.45 (0.44–4.71)	0.540	2.18 (0.88–5.37)	0.091	1.38 (0.38–5.01)	0.622
Clinical audit	2.56 (0.89–7.32)	0.080	1.77 (0.35–8.86)	0.488	2.43 (0.79–7.47)	0.122	1.87 (0.32–11.12)	0.489
Clinical trial or feeding study	1.69 (0.58–4.94)	0.341	2.35 (0.56–9.91)	0.244	3.44 (0.97–12.17)	0.055	2.89 (0.50–16.58)	0.234
Data collection (No data collection)								
Original data collection included	1.40 (0.74–2.67)	0.305	0.59 (0.19–1.82)	0.357	**2.05 (1.02–4.11)**	**0.043**	1.35 (0.39–4.72)	0.641
Involvement in overall process (Low)								
High involvement in overall process	**5.51 (1.97–15.45)**	**0.001**	**6.13 (2.03–18.49)**	**0.001**	2.24 (0.96–5.25)	0.063	2.17 (0.80–5.90)	0.128
Overall model			**χ2 (7) = 18.244**	**0.011**			χ^2 (9) = 14.955	0.092

Statistically significant differences are highlighted in bold.

[a]'High confidence' in overall research skills represents those reporting either '4, A lot' or '5, A great deal' of confidence in their overall research skills after completing their research project

[b]'Improved confidence' in overall research skills represents those whose confidence in their overall research skills increased by one or more on the Likert scale after completing their research project.

Abbreviations: CI, confidence interval; OR, odds ratio.

$p = 0.035$) and the student reporting 'high levels of involvement in the overall research process' (OR = 5.51, 95% CI = 1.97–15.45, $p = 0.001$). However, following multivariable logistic regression the only factor significantly associated with high confidence in overall research skills was having 'high levels of involvement in the overall research process' (OR = 6.13, 95% CI = 2.03–18.49, $p = 0.001$). The multivariable regression model was statistically significant ($\chi^2 = 18.244$, $df = 7$, $p = 0.011$).

In total, 113 (70.6%) students reported improvement in their overall research skills after the project, and the odds of this outcome was also analysed using logistic regression (Table 6). Following univariate logistic regression, the only statistically significant factors were 'university' (King's College London OR = 2.27, 95% CI

= 1.10–4.71, $p = 0.027$) and 'undertaking original data collection' (OR = 2.05, 95% CI = 1.02–4.11, $p = 0.043$). However, following multivariable logistic regression, no factors were statistically significant associated with having improved confidence in research skills and the model itself was not statistically significant ($\chi^2 = 14.955$, $df = 9$, $p = 0.092$).

DISCUSSION

Research is a cornerstone of dietetic practice, and a lack of confidence in research skills is a commonly reported barrier to dietitians undertaking research.[14,21,25] Research skills are commonly taught at university by experiential learning involving students undertaking a research project. The present study aimed to investigate attitudes towards research and confidence in research skills among student dietitians before and after a research project.

Students held largely positive attitudes towards research, both at baseline and after the research project (Table 2). Indeed, the only statement for which the majority did not hold positive views was 'seeing patients is more important than research', for which 44%–45% reported neutral ('neither agree, nor disagree') rather than negative views, reflecting the reality that neither seeing patients, nor doing research are more important. The attitudes towards research reported by student dietitians were, in general, similar or more positive than those reported by registered dietitians in a previous survey from which the questionnaire was taken.[14] For example, after completing their project, there were great proportions of students agreeing that 'Research should be carried out by all dietitians' (students 59.4%, dietitians 38%) and disagreeing that 'I don't see research as part of a dietitian's job' (students 75.6%, dietitians 60%).[14] Overwhelmingly positive attitudes to research at baseline might reflect students' early introduction to the importance of research at university, their ongoing exposure to research through coursework and direct contact with researchers within their university, at the same time as the lack of exposure to some of the barriers to undertaking research within the practice setting.

Improvements in attitudes were only demonstrated in a small proportion of students during the research project and the number of students with a positive attitude after the project was rarely statistically significantly greater than before the project. This may be a result of ceiling effects because of the high proportion of positive responses to attitude statements observed at baseline or perhaps because their research project has given them realistic expectations of research involvement within dietetics. The only statistically significant improvement in attitudes occurred for the statement 'I find it hard to interpret research findings', which notably was the only attitude related to students' own skills as opposed to addressing general attitudes towards research among dietitians.

Participation in the research project had little impact on expectations for future research involvement (Table 3). This contrasts with many studies in different countries or different disciplines. For example, evaluations of student dietitians in Australia,[3] student dietitians and dietitians in the USA,[32] science students in the USA,[33] and medical and allied health students in South Africa[34] have reported a university research project as a driver for future research involvement, including the prospect of future PhD studies. However, in these examples, undertaking a research project at university is generally elective, and therefore may select students already interested in developing a research career, whereas, in the present study, the research project module was compulsory. As well as expectations for future research involvement, a previous study across a range of disciplines has reported that university research projects increase students' self-reported preparedness and opportunities for a postgraduate research career,[35] although this was not measured in the present study.

Undertaking a research project improved confidence in research skills in many students and in many aspects of the research process and was evident both when students were asked to rate their own research skills (Table 4), as well as for their perception of the extent to which the project enhanced their research skills (Table 5). More than half of students reported improvements in confidence for nine of the 10 research skills and, at the end of the project, almost half reported high levels of confidence (49.4%) and almost three-quarters (70.6%) had improved confidence in the overall research process.

These findings concur with a previous large study in over 10,000 students in the USA from science, technology, engineering, medicine and social sciences, where 83% reported improved confidence in research skills following a university research project.[36] Within dietetics, a relatively small health discipline, there are inevitably only much smaller studies. Positive effects on research skill development following participation in a research project has been reported in 18 student dietitians in Australia,[30] 13 student dietitians volunteering as research assistants in the USA[37] and 55 student dietitians undertaking an online simulated research project in the USA.[15]

The present study is therefore the largest analysis to date demonstrating the positive effects on research skills in student dietitians and, importantly, enabled an exploration of the factors associated with confidence. Many project-related factors were explored, including the supervision model/location (internal vs. external), the type of project (e.g., experimental laboratory, dietary survey, etc.) and whether original data was collected, many of which are themselves related, highlighting the importance of multivariable regression analysis to test for independent associations. Indeed, the only factor

independently associated with high confidence in the overall research process was having high levels of involvement in the overall research process. This has been previously alluded to in the wider literature outside of health professional education. For example, a previous study shows greater perceived benefit to skills when undertaking research projects of greater duration,[38] whereas another study reports that scores on a research proposal assessment at the start of graduate school was associated with the duration and autonomy of experience during their undergraduate research project.[39]

It is encouraging that the only factor related to high confidence in overall research skills was high levels of involvement in the overall research process, which resulted in a more than six-fold greater odds of high confidence and was more important than other project-related factors (e.g., supervision model, type of project, collection of original data). Offering variety in opportunities in project type can be challenging in some university settings as a result of access to laboratory facilities, the research interests of academic staff and the existence of established external collaborations. However, the present study reinforces that, irrespective of these other factors, the most important goal is to offer research projects that enable as much involvement in the overall research process as possible, thus emphasising the role of experiential learning (learning by doing) in research skills development.

Reassuringly, personal characteristics (age, gender, university, previous research experience) were not significantly associated with high confidence or improved confidence. Two project-related factors are worthy of comment: the supervision model/location and the project type. Projects that were undertaken externally and supervised by both an internal and an external supervisor were associated with greater odds of high confidence on univariable but not multivariable analysis. The positive effect of collaborative supervision is congruent with previous studies.[31,40,41] The type of project undertaken was not significantly associated with high confidence or improved confidence on either univariate or multivariate analysis. Clinical audit, a common method of data collection and evaluation in dietetic practice, resulted in similar levels of high confidence and improved confidence as other project types. However, given the five different categories of project type, the study may have been underpowered to detect association with such low event rate.

Research projects vary widely in the extent to which they involve different activities in the research process. Given the relationship between high levels of involvement and high confidence in research skills, the limited confidence in specific skills such as 'developing a hypothesis' and 'obtaining research ethics approval' is unsurprising. The short duration of the research project (usually 3–4 months part time) means that students are seldom involved in the early stages of project conception, design and approval. As such, these areas where involvement and confidence are low, may benefit from being further incorporated into the teaching curriculum and into future research projects. In addition, on circulating research project titles, supervisors could indicate the likely levels of involvement in different aspects of the research process so that students can select a project more likely to fit their learning needs, as well as their interests.

Undertaking a final year research project has been described as a 'high impact educational experience'[42] but requires intensive and often 1:1 supervision from a university academic. Indeed, it has been argued that it is not only the activities of the research project that promote learning, but also the intensive supervision, the close interactions with academics and researchers, and the integration of students into the research fabric of university life that provides a unique educational experience unlike that of lectures and seminars.[35] Despite this, competing curricula demands has been reported as the most common barrier to teaching research skills in pre-registration programmes in nursing, midwifery and allied health.[43] Given the intensive nature of research project supervision and the busy curricula in dietetic education, it is important that there are demonstrable educational outcomes to justify research projects as a highly effective method of teaching research skills – justification that this evaluation now provides.

In the present study, all students undertook a research project; however, it would be interesting to compare the attitudes and confidence in research skills of those who do (intervention) and do not (control) undertake a research project. Such a control group would be challenging in the UK environment where a research project is commonly a compulsory component in the final year of a Bachelors degree in dietetics. In other countries, including Australia, Canada and the USA, such comparisons can be made; however, students are not randomly selected to do a research project or not, and so selection bias might result in the most research-orientated students carrying out a research project and therefore would impact conclusions.

Strengths and limitations

This is the largest study directly comparing student dietitians' attitudes to research and confidence in their research skills before and after undertaking a research project. It has used identical questionnaires items and response sets at baseline and after the project to enable direct comparison. However, the questionnaires were not validated prior to use, although the attitude statements were adapted from a previous survey investigating dietitians' attitudes towards research.[14] The lack of validity and reliability testing may introduce variation in student responses, whereas social desirability bias may

lead some students to exaggerate attitudes and confidence, although statistical analysis was still able to identify findings that were statistically significant and theoretically plausible. Different questionnaires have subsequently been used to measure attitudes to research[13,32] and confidence in research skills[19] and some instruments have undergone psychometric testing of phenomena including research involvement,[44,45] and such questionnaires may be used in future studies.

The large sample size enabled investigation of the factors independently associated with high confidence and improved confidence through multivariable logistic regression. The lack of exclusion criteria and high response rate (81.6%) minimised selection bias. Using a complete case analysis of only those students who completed a questionnaire at both time points avoided the need for data imputation, although this may have resulted in the inclusion of only those students who successfully completed the research project module, and therefore may have inflated improvements in confidence in research skills. The sample was mostly young and mostly female, although this is largely representative of student dietitians in the UK. Although the questionnaire surveys were conducted contemporaneously to the research projects, these were conducted more than 10 years ago. However, we do not consider this will impact data integrity and interpretation because the research project modules are still undertaken in the same style at the two universities and there is no reason to assume that student cohorts have changed during this period. Furthermore, this evaluation was performed at only two universities and, although there may be differences in the content and delivery of research training provided compared to other universities, the quality of the research training in pre-registration dietetics programmes is likely representative of other universities in the UK.

The present study is also limited in that it only measured students' self-reported confidence in research skills. Student reports of research skills has been shown to lack agreement with academic and performance-based assessment of research skills.[46] One study has shown that students who had previously undertaken a research project as an undergraduate had higher scores for a research proposal assessment at the start of their PhD compared to those who had not undertaken such a project.[39] Academic or performance-based assessments were not used in the present study because using official university grades awarded for the research project module may have limited participation in this evaluation and because students' perceptions of their learning remain an important educational outcome of a reflective practitioner. However, tangible outcomes, such as the number of research projects that students then presented at conferences or published as full manuscripts, or the number of students progressing to Masters or Doctoral degrees, would be 'real-world' outcomes following completion of a university research project and should be included in future studies in this area.

Finally, the data collected were exclusively quantitative. Qualitative enquiries may help bridge the gap between the generally positive attitudes toward research and actual research involvement, as well as provide in-depth insight into how the research project may impact attitudes to research and confidence in research skills.

CONCLUSIONS

Student dietitians exhibit generally positive attitudes towards research. In general, undertaking a research project did not improve attitudes to research but did improve students' confidence in their research skills. High levels of involvement in the overall research process was the only significant factor associated with high confidence in overall research skills. This suggests that, regardless of personal or project-related characteristics, so long as student dietitians are highly involved in the research process, they have six-fold greater odds of achieving high confidence after undertaking a research project. Whether these improvements in confidence are sustained and translate into future research involvement in practice warrants further investigation.

AUTHOR CONTRIBUTIONS

Conceptualisation, study design, and data collection: Kevin Whelan, Jane E. Thomas and Angela M. Madden. *Data analysis and interpretation*: Kevin Whelan, Kate R. Castelli, Camilla Trizio and Oliver Howard. *Manuscript preparation*: Kevin Whelan. *Manuscript review and approval*: Kevin Whelan, Kate R. Castelli, Camilla Trizio, Oliver Howard, Jane E. Thomas and Angela M. Madden. All authors critically reviewed the manuscript and approved the final version submitted for publication.

ACKNOWLEDGEMENTS

We thank the students for completing questionnaires, and the academics and external dietitians and nutritionists who supervised research projects. The study did not receive any funding.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

TRANSPARENCY DECLARATION

The authors affirm that this manuscript is an honest, accurate and transparent account of the study being reported. The authors affirm that no important aspects of the study have been omitted and that any discrepancies from the study as planned have been explained.

ETHICAL STATEMENT

The study received ethical approval from the research ethics committees of both King's College London and London Metropolitan University.

ORCID

Kevin Whelan http://orcid.org/0000-0001-5414-2950
Angela M. Madden http://orcid.org/0000-0001-6353-6492

REFERENCES

1. Dougherty CM, Burrowes JD, Hand RK. Why registered dietitian nutritionists are not doing research—perceptions, barriers, and participation in research from the academy's dietetics practice-based research network needs assessment survey. J Acad Nutr Diet. 2015;115:1001–7.
2. Daniels L. A bright future for dietitians - where's the evidence? Nutr Diet. 2002;59:29–36.
3. Desbrow B, Leveritt M, Palmer M, Hughes R. Evaluation of a curriculum initiative designed to enhance the research training of dietetics graduates: research competencies for graduate dietitians. Nutr Diet. 2014;71:57–63.
4. Neale EP, Tapsell LC. Perspective: the evidence-based framework in nutrition and dietetics: implementation, challenges, and future directions. Adv Nutr. 2019;10:1–8.
5. Boaz A, Hanney S, Jones T, Soper B. Does the engagement of clinicians and organisations in research improve healthcare performance: a three-stage review. BMJ Open. 2015;5: e009415.
6. Dietitians Association of Australia. National competency standards for dietitians. 2021 [Last accessed 30th March 2022]. Available from: https://dietitiansaustralia.org.au/working-dietetics/standards-and-scope/national-competency-standards-dietitians
7. Partnership for Dietetic Education and Practice. Integrated competencies for dietetic education and practice. 2020 [Last accessed 30th March 2022]. Available from: https://www.pdep.ca/library/PDEP-Policies/Integrated-Competencies-For-Dietetic-Education-And.aspx
8. Health and Care Professions Council. Standards of proficiency – dietitians. 2013 [Last accessed 30th March 2022]. Available from: https://www.hcpc-uk.org/globalassets/resources/standards/standards-of-proficiency—dietitians.pdf?v=637018068040000000
9. American Dietetic Association. American Dietetic Association: standards of practice and standards of professional performance for registered dietitians (competent, proficient and expert) in extended care settings. 2011 [cited 2021 Nov]. Available from: https://jandonline.org/action/showPdf?pii=S0002-8223%2811%2900004-6
10. International Confederation of Dietetic Associations. International Competency Standards for Dietitians-Nutritionists [Last accessed 30th March 2022]. Available from: https://www.internationaldietetics.org/Downloads/International-Competency-Standards-for-Dietitian-N.aspx#:~:text=The%20ICDA%20Competency%20Standards%20for,development%20throughout%20their%20professional%20life
11. Hren D, Lukić IK, Marusić A, Vodopivec I, Vujaklija A, Hrabak M, et al. Teaching research methodology in medical schools: students' attitudes towards and knowledge about science. Med Educ. 2004;38:81–6.
12. Björkström ME, Johansson IS, Hamrin EKF, Athlin EE. Swedish nursing students' attitudes to and awareness of research and development within nursing. J Adv Nurs. 2003;41: 393–402.
13. Byham-Gray LD, Gilbride JA, Dixon LB, Stage FK. Evidence-based practice: what are dietitians' perceptions, attitudes, and knowledge? J Am Diet Assoc. 2005;105:1574–81.
14. Harrison JA, Brady AM, Kulinskaya E. The involvement, understanding and attitudes of dietitians towards research and audit. J Hum Nutr Diet. 2001;14:319–30.
15. Arts J, Paulin C, Lofgren IE, Woodland B, English C. Evaluation of dietetic interns' research skills in an online, non-thesis Master's program. Top Clin Nutr. 2020;35:277–84.
16. Whelan K, Madden AM, Thomas JE. Student dietitians' attitudes towards research and audit: a comparison with registered dietitians. J Hum Nutr Diet. 2007;20:121–5.
17. Pickstone C, Nancarrow S, Cooke J, Vernon W, Mountain G, Boyce RA, et al. Building research capacity in the allied health professions. Evid Policy. 2008;4:53–68.
18. Pager S, Holden L, Golenko X. Motivators, enablers, and barriers to building allied health research capacity. J Multidiscip Healthc. 2012;5:53–9.
19. Howard AJ, Ferguson M, Wilkinson P, Campbell KL. Involvement in research activities and factors influencing research capacity among dietitians. J Hum Nutr Diet. 2013;26:180–7.
20. Morley-Hauchecorne C, Lepatourel JA. Self-perceived competence of clinical dietitians to participate in research: a needs assessment. Can J Diet Pract Res. 2000;61:6–12.
21. Slawson D, Clemens L, Bol L. Research and the clinical dietitian: perceptions of the research process and preferred routes to obtaining research skills. J Am Diet Assoc. 2000;100:1144–8.
22. Anchondo IM, Campbell C, Zoellner J. Academy of nutrition and dietetics 2011 survey on member research activities, needs, and perceptions. J Acad Nutr Diet. 2014;114:803–10.
23. Boyd M, Byham-Gray L, Touger-Decker R, Marcus AF, King C. Research interest and research involvement among us registered dietitian nutritionists. Top Clin Nutr. 2016;31:267–77.
24. Byham-Gray LD, Gilbride JA, Dixon LB, Stage FK. Predictors for research involvement among registered dietitians. J Am Diet Assoc. 2006;106:2008–15.
25. King C, Parrott JS, Hand R. A cross-sectional exploration of research outcome expectations: motivators for dietetics research involvement. Top Clin Nutr. 2016;31:147–67.
26. Madden A. Research – what are our options? J Hum Nutr Diet. 2002;15:417–8.
27. British Dietetic Association. A curriculum framework for the pre-registration education and training of dietitians – revised edition 2020. 2020 [cited 2021 Nov]. Available from: https://www.bda.uk.com/uploads/assets/885f4aba-12cb-4557-973016da2e5e0516/BDACurriculum2020FINAL0505.pdf
28. Vandiver DM, Walsh JA. Assessing autonomous learning in research methods courses: Implementing the student-driven research project. Act Learn High Educ. 2010;11:31–42.
29. Yardley S, Teunissen PW, Dornan T. Experiential learning: transforming theory into practice. Med Teach. 2012;34:161–4.
30. Davidson ZE, Palermo C. Developing research competence in undergraduate students through hands on learning. J Biomed Educ. 2015;2015:1–9.
31. Whelan K, Thomas JE, Madden AM. Student research projects: the experiences of student dietitians, university faculty members, and collaborators. J Am Diet Assoc. 2007;107:1567–74.
32. Tan S-Y, Hemmelgarn M, Baumgardner K, Tucker RM. Attitudes towards and experiences with research: differences between dietetics students and professionals in Australia and the United States. Nutr Diet. 2017;74:388–95.
33. Lopatto D. Survey of Undergraduate Research Experiences (SURE): first findings. Cell Biol Educ. 2004;3:270–7.
34. Bovijn J, Kajee N, Esterhuizen TM, Van Schalkwyk SC. Research involvement among undergraduate health sciences students: a cross-sectional study. BMC Med Educ. 2017;17:186.
35. Craney C, McKay T, Mazzeo A, Morris J, Prigodich C, de Groot R. Cross-discipline perceptions of the undergraduate research experience. J High Educ. 2011;82:92–113.
36. Russell SH, Hancock MP, McCullough J. Benefits of undergraduate research experiences. Science. 2007;316:548–9.
37. Brehm BJ, Rourke KM, Cassell C. Enhancing didactic education through participation in a clinical research project. J Am Diet Assoc. 1999;99:1090–3.
38. Bauer KW, Bennett JS. Alumni perceptions used to assess undergraduate research experience. J High Educ. 2003;74:210–30.

39. Gilmore J, Vieyra M, Timmerman B, Feldon D, Maher M. The relationship between undergraduate research participation and subsequent research performance of early career STEM graduate students. J High Educ. 2015;86:834–63.
40. Thompson CJ, McNeill JA, Sherwood GD, Starck PL. Using collaborative research to facilitate student learning. West J Nurs Res. 2001;23:504–16.
41. Hays JE, Peterson CA. Use of an outcomes research collaborative training curriculum to enhance entry-level dietitians' and established professionals' self-reported understanding of research. J Am Diet Assoc. 2003;103:77–84.
42. Association of American Colleges & Universities. High-impact educational practices. 2014 [Last accessed 30th March 2022]. Available from: https://www.aacu.org/node/4084
43. Council of Deans of Health. Becoming research confident. research in pre-registration curricula for nursing, midwifery and allied health programmes in the UK. 2019 [Last accessed 30th March 2022]. Available from: https://www.councilofdeans.org.uk/2019/05/new-report-becoming-research-confident-research-in-pre-registration-curricula-for-nursing-midwifery-and-allied-health-programmes-in-the-uk
44. Plant MK, Marcus AF, Ziegler J, Byham-Gray L. Testing of a tool to measure practice-based research involvement for registered dietitian nutritionists in clinical practice. Topics Clin Nutr. 2017;32:47–59.
45. Whelan K, Copeland E, Oladitan L, Murrells T, Gandy J. Development and validation of a questionnaire to measure research involvement among registered dietitians. J Acad Nutr Diet. 2013;113:563–8.
46. Feldon DF, Maher MA, Hurst M, Timmerman B. Faculty mentors', graduate students', and performance-based assessments of students' research skill development. Am Educ Res J. 2015;52:334–70.

AUTHOR BIOGRAPHIES

Kevin Whelan PhD RD, is Professor of Dietetics and Head of Department of Nutritional Sciences at King's College London.

Kate R. Castelli MSc RD, was a Research Student at the Department of Nutritional Sciences at King's College London and is currently a Clinical Lead Dietitian at Lancashire Teaching Hospitals NHS Foundation Trust.

Camilla Trizio BA, is a Research Student at the Department of Nutritional Sciences at King's College London.

Oliver Howard BSc RD, was a Research Student at the Department of Nutritional Sciences at King's College London and is currently Specialist Gastroenterology Dietitian at Medway NHS Foundation Trust.

Jane E. Thomas MMedSci RD, was Programme Director for Dietetics and is currently Visiting Senior Lecturer in the Department of Nutritional Sciences at King's College London.

Angela M. Madden PhD, RD, was formerly Senior Lecturer in Nutrition and Dietetics at London Metropolitan University and is currently Clinical Researcher in Nutrition and Dietetics at the University of Hertfordshire.

How to cite this article: Whelan K, Castelli KR, Trizio C, Howard O, Thomas JE, Madden AM. Undertaking a research project improves confidence in research skills among student dietitians. J Hum Nutr Diet. 2022;35:934–947. https://doi.org/10.1111/jhn.13004

Received: 12 January 2022 | Accepted: 14 March 2022

DOI: 10.1111/jhn.13011

JHND Journal of Human Nutrition and Dietetics | BDA The Association of UK Dietitians

Review of dietary assessment studies conducted among Khmer populations living in Cambodia

Janelle L. Windus | **Kerith Duncanson** | **Tracy L. Burrows** | **Clare E. Collins** | **Megan E. Rollo**

School of Health Sciences, Faculty of Health and Medicine, University of Newcastle, Newcastle, NSW, Australia

Correspondence
Janelle L. Windus, School of Health Sciences, Faculty of Health and Medicine, University of Newcastle, University Drive, Callaghan, NSW 2308, Australia.
Email: janelle.windus@uon.edu.au

Abstract

Background: Despite economic growth, Cambodia continues to have high rates of malnutrition, anaemia and nutrition-related deficiencies. Government policies promote nutrition strategies, although dietary intake data is limited. A detailed synthesis of existing intake data is needed to inform nutrition policy and practice change. This review aims to characterise and assess quality of dietary assessment methods and outcomes from individual-level 'whole diet' studies of Khmer people living in Cambodia.

Methods: Searches were conducted using PRISMA-ScR guidelines. Included papers reported dietary intake at an individual level for 'whole diet'. Studies using secondary data or lacking dietary assessment details were excluded. Extracted data included dietary assessment features, nutrient/food group intakes and database.

Results: Nineteen publications (15 studies) were included, with nine carried out among children under 5 years and six among women. Eleven studies reported intake by food groups and four by nutrients, prominently energy, protein, vitamin A, iron, calcium and zinc. Inconsistent intakes, food groupings and reporting of study characteristics limited data synthesis. All but one study used 24-h recalls. Trained local fieldworkers used traditional interview-administered data collection and varied portion estimation tools. Food composition databases for analysis were not tailored to the Cambodian diet. Overall quality was rated as 'good'.

Conclusions: We recommend the development of a best-practice protocol for conducting dietary assessment, a Cambodia-specific food composition database and a competent trained workforce of nutrition professionals, with global support of expertise and funding for future dietary assessment studies conducted in Cambodia.

KEYWORDS

Cambodia, dietary assessment, dietary intake, food composition database, review

Key points

- Fifteen studies with highly variable intake data included in the review.
- The food composition databases used were not specific to Cambodian diet.
- Minimum reporting standards and best practice protocols recommended, including in-country nutrition training.
- Lack of whole population dietary intake data indicates the need for a national survey.

INTRODUCTION

The health of Cambodia's Khmer population continues to be adversely impacted secondary to the devastation inflicted on society during Khmer Rouge regime from 1975 to 1999.[1] Cambodia is currently classified as a low-middle income country (LMIC), with poverty manifested by high rates of poor hygiene, sanitation and nutritional status coupled with inadequate health services.[2,3] Poor nutritional status is indicated by relatively high rates of underweight (24%), stunting (32%) and wasting (10%) among children aged under 5 years (i.e., high compared to neighbouring Thailand and Vietnam, and similar to Laos),[4] underweight among women of reproductive age (WRA) (14%) and moderate (37%) levels of food insecurity.[5,6] A growing proportion of malnourished women (18%) and children (2%) have overweight or obesity, amplifying the double burden of malnutrition.[6] The prevalence of anaemia remains high for children under 5 years (56%) and women (44%),[6] despite targeted programmes and government initiatives attempting to counter this situation. Nutritional deficiencies remain prevalent, with zinc deficiency rates of 73%–90% among children,[7,8] 19% for folate among women, and 33% and 60% for vitamin D in children and women, respectively.[6] Vitamin A rates (9% in 2014) in women have decreased since 2000.[6]

Dietary patterns in Cambodia reflect the communal lifestyle of the Khmer people, who share family meals that feature rice, soup, sweet stew and fish.[9] Typical Khmer diets lack adequate meats, vegetables and fruit, reflecting widespread poverty rather than the unavailability of these food items in Cambodia.[10] Energy dense snacks high in fat, sugar and salt are commonly consumed, particularly by children.[11] Along with condiments high in salt such as fish sauce, soy sauce and monosodium glutamate, as well as added salt, these contribute to the common unhealthy dietary patterns.

Global health agencies and non-government organisations have partnered with the Cambodian government to address key nutritional and food security issues amongst Cambodians.[12,13] This primarily focuses on malnutrition-related strategies for mothers and children. These include the first National Nutrition Strategy 2009–2015,[14] a National Nutrition Program's fast track road map for improving nutrition 2014–2020,[15] the National strategy for food security and nutrition 2019–2023,[2] and the Cambodia Nutrition project with World Bank.[16] Additionally, international researchers have conducted cross-sectional studies and interventions to inform further policy and programme development.[12,13] Ninety percent of these studies reported being funded by external agencies, many in partnership with the Cambodian government.[13]

These strategies are consistent with the Sustainable Development Goals for ending hunger and all forms of malnutrition by 2030.[17] Despite nutrition policy and strategy prioritisation in Cambodia, there are no goals or strategies to specifically address nutritional adequacy of dietary intakes. The most specific policy reference to dietary intake is to 'increase availability of information through improved monitoring, evaluation and research' (strategy 7.5; NNS[14]). Currently Cambodia lacks national nutrient reference values for children aged under 5 years and adults, although, recently, the Cambodian government developed 'Cam-RDA' nutrient reference values for school-age children.[18]

Food consumption surveys assess the dietary intake of individuals or groups aiming to examine nutrient adequacy of population intake and also diet–disease relationships so that these can inform national nutrition and health policies.[19] Individual-level dietary assessment in Khmer populations is problematic because of challenges such as estimation of individual portions eaten from shared plates.[20] The absence of a comprehensive Cambodian-specific food composition database (FCD) further limits any accurate evaluation of nutrient adequacy of Khmer populations and specific age groups within the population.[21,22]

Published studies about dietary intake in LMICs often do not describe the dietary assessment methods used in a comprehensive or systematic manner.[23] Low rigour and poor study quality limit generalisability of the study findings and potentially can result in misleading recommendations or inappropriate strategy implementation.[24] Guidelines such as STROBE-nut[25] were developed to improve the global quality of nutrition intervention reporting, and the European Micronutrients Recommendations Aligned Network of Excellence (EURRECA)[26] tool is available for assessing the quality of dietary intake validation studies.

Our recent scoping review included 100 food and nutrition studies with Khmer living in Cambodia, of which 42 involved a nutrition intervention, 76 were dietary assessment studies and 18 involved both nutrition intervention and assessment components.[13] Two-thirds (68%) of studies were conducted among WRA and young children, and predominantly focused on malnutrition-related issues and anaemia.[13] Thirty-five dietary assessment studies explored a specific dietary component (vitamin A-rich foods, sugar-containing foods, snack foods) or a single food such as rice or fish, rather than having an overall or 'whole diet' focus. The review provided a comprehensive overview of nutrition research conducted in Cambodia to date, but the intentionally broad inclusion criteria, diversity of primary outcomes and variability in dietary assessment methods used limited the comparison of outcomes between the included studies. Additionally, characteristics relating to dietary assessment methods and FCDs were not the primary focus and so methodological quality was not comprehensively investigated.

To better understand the dietary intake of Khmer people living in Cambodia, in-depth analysis and

synthesis of data and the methods used in dietary assessment-specific studies were identified as an urgent need for further informing future research. In particular, there is a need for evidence relating to the relationships between nutrition and health, as well as the reporting of food and/or nutrient intakes at the individual level.[27]

The primary aim of the current review was to characterise food and/or nutrient intake outcomes and associated dietary assessment methods in studies that evaluated 'whole diet' among Khmer people living in Cambodia. A secondary aim was to evaluate the quality of dietary assessment methods used in these individual-level dietary intake studies.

METHODS

The initial search was conducted in May 2020, and an updated search was performed in November 2021, following the PRISMA-ScR protocol.[28] The full search strategy is described in Windus et al.[13] Briefly, five databases (Medline, CINAHL, Embase, Cochrane library and Scopus) were searched using specific keywords related to nutrition, health, diet, food and Cambodia. Grey literature searches included Google Scholar and websites for Cambodian government and several global health organisations.

After removing duplicates, each study was screened by two reviewers by title and abstract, then full-text articles were independently evaluated by two reviewers against the inclusion/exclusion criteria. Conflicts at both stages were resolved by a third reviewer. Studies were included if they were conducted among Khmer people living in Cambodia, and included dietary assessment, which could be but was not limited to observation, self-report or proxy surveys. Included papers reported dietary intake at an individual level for the 'whole diet'. To be eligible as a 'whole diet', studies collected dietary intake on nutrients and/or food groups that reflected a complete dietary intake. Studies were excluded if they collected partial dietary intake such as single specified food items (e.g., rice, fish, sugar-containing snacks), one food group (e.g., meats, complementary foods, breast-milk substitutes) or foods rich in a single nutrient (e.g., vitamin A-rich foods). Qualitative studies and articles pre-dating 1993 or in languages other than English or Khmer were excluded. Studies were excluded if there was only secondary data analysis (rather than primary data), collected household-level intake, or they used indirect methods such as food balance sheets. Studies that did not report on the dietary assessment methods used or results of dietary intake were also excluded. Screening of included studies was conducted by two reviewers and 13 conflicts were resolved by discussion and consensus.

Data from included 'whole diet' dietary assessment studies were extracted by the lead reviewer and checked by a second reviewer. Extracted data included dietary assessment features/tools, validation status, nutrient or food group intake measured, FCDs and nutrition adequacy standards used. Dietary assessment methods were categorised as 'validated' when the study indicated use of a validated tool.

The EURRECA[26] scoring system was selected as a quality assessment tool as a result of applicability for dietary assessment studies. Two reviewers independently scored each study based on sampling, statistics, administration, seasonality and supplements, with a score < 2.5 rated as 'poor', 2.5 to < 3.5 as 'reasonable', 3.5 to < 5.0 as 'good' and 5.0–7.0 as 'very good'. Steps two and three assess correlations of validation studies and thus were not used.

RESULTS

The literature search identified 4109 titles, of which 293 full text articles were assessed for inclusion and a further 274 were excluded. Two hundred and fifty-five articles were excluded based on study type, characteristics or design, 35 were excluded because they did not report intake of the 'whole diet', 12 studies did not use primary data, seven studies collected household rather than individual dietary intake, and eight did not fully described the dietary assessment methods used (Figure 1). Of the resulting 19 publications, seven reported on the same three studies, and the remaining 12 publications were individual studies. Therefore, 15 studies were included in this review, with the publications from the same study differentiated by the first author's name and year.

Eight studies reported on nutrition interventions, including three home food production interventions,[29–33] a local food-based supplement,[34] iron and zinc supplements,[35] and a lunch provision study.[36] Nine were cross-sectional dietary intake assessment studies[6,7,9,11,18,37–40] and two reported on validation of a dietary assessment tool.[41,42]

Table 1 presents detailed characteristics and dietary assessment features of the included studies. Participants in nine studies were children under 5 years of age, six studies included WRA, two studies involved school-age children, one included adult women only and one study in an adult population involved predominantly (63%) women participants. Nine studies reported food group intake, four reported nutrient intake and two reported collecting both.

Dietary intake reported in studies that assessed 'whole diet' intake in Cambodia

Pooling of absolute dietary intakes by nutrient and/or food group was not possible because of the variability in the data collection and/or reporting and the small

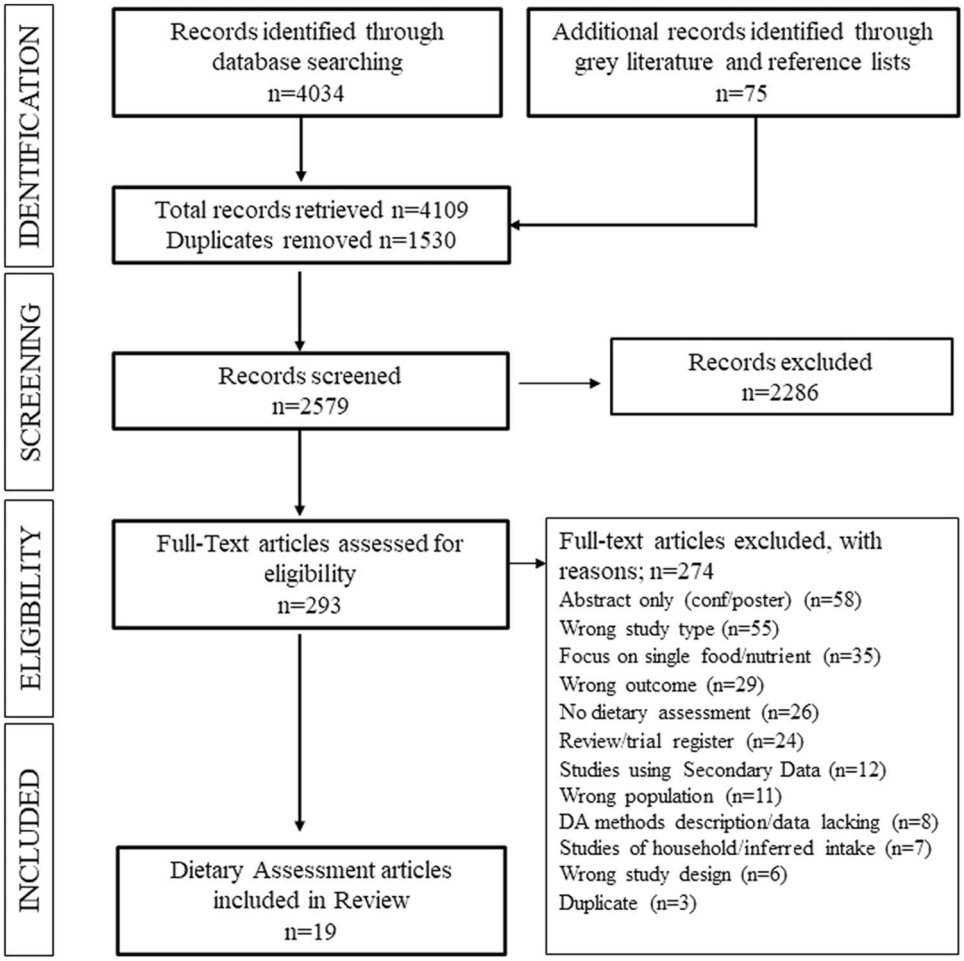

FIGURE 1 PRISMA flow diagram of article identification and inclusion in review of dietary assessment individual-level whole diet studies in Khmer populations living in Cambodia. DA, dietary assessement

representation by each population subgroup. However, a synthesis of the study data is summarised in Table 2.

Intakes spanning 20 nutrients were reported (see Supporting information, Supplementary Tables S1 and S2). Vitamin A and iron were reported in all six studies, with protein, calcium, zinc and energy also commonly reported. Children's reported intakes of vitamin A (151–353 μg RE) and calcium (152–278 mg) varied considerably between studies, whereas macronutrient intakes were fairly consistent between studies. Reported intakes were higher for school-age boys than girls, and inconsistent variability was evident among WRA. In studies that reported dietary or nutrient adequacy, moderate to high proportions of children were inadequate in vitamin A (45%–81%), iron (36%–78%), calcium (76%–99%) and zinc (53%–92%), whereas 50%–89% WRA were inadequate in iron intake.

Eleven studies reported food group intakes, most commonly as amounts in grams or proportion of participants consuming it (see Supporting information, Supplementary Table S3). The number of food groups reported ranged from six to 33. Categorisation of food groups was inconsistent between studies; for example, vegetable groupings included vitamin A rich vegetables, dark green leafy vegetables, other vegetables, white tubers and roots, or combined fruit and vegetables (see Supporting information, Table S4). Excluding breastmilk for infants, cereals/grains were consistently the most consumed food group by all population groups, followed by flesh foods (such as meats, fish) and vegetables. High intakes of snack foods among children from six months old was evident, whereas younger children reported higher intakes of milk/dairy than school-age children, and WRA intakes varied widely. Fruit intake was moderate across all groups, whereas condiments/spices were a common diet component for WRA.

Of the eight studies of infants, four[7,32–34,38] accounted for breastmilk intake by applying estimated quantities from World Health Organization,[43] according to breastfeeding status (partial or exclusive) and age (up to 12 months only). Bunthang *et al.*[37] reported breastfeeding rates for exclusively breastfed infants under 6 months old, although they did not account for the contribution of breastmilk to the nutrient intakes for

TABLE 1 Characteristics and features of included studies for review of dietary assessment studies conducted in Cambodia.

Study | Organisation | Funding body |	Population | Study type | Year | DA method	Dietary assessment features			Dietary intake: nutrients or food groups (FG)	Food composition database (FCD)	Quality score
		Portion estimation	Administration	Addressing bias/error			
Anderson *et al.* (2008) | University (NZ) | University (NZ) | [7]	Child < 5 years old *n* = 251 stunted toddlers 1–4 years old; (15% PBF and 85% NBF), recruited from urban slum village | cross-sectional |2003 | MP 24 R(1), WFR	• Food models • Calibrated HH measures • Weighed portions of rice/fruit/snacks • Collected mixed dishes recipes • Estimated portion from recipe • Estimated BM intake[43]	• Interview-assisted • RA training	• List sampling • All days of week and weekend represented • Used validated 24 R tool[45]	• 12 Nutrients:energy, protein, vit A, thiamine, riboflavin, niacin, vit C, Ca, PO_4, Fe, Zn, Cu	• Specially developed 238-item • Thai FCD • ASEAN FCD • Chemical analyses	3.0 Reasonable
Bunthang *et al.* (2014) | Royal government of Cambodia | University (USA) | [37]	Child < 5 years old and WRA/mothers *n* = 300 mothers with *n* = 342 child 6–59 months; recruited from 3 rural lake provinces | cross-sectional | 2014 |24 R (1), R-WFR, BFF	• Real food models • Use of standard HH equipment • Weighed estimated portions • Mother estimated child's portion of shared plate • No BM intake included	• Interview-assisted • RA training	• Simple randomised sampling from 3 provinces • Recall days not stated • Tool pre-tested • Data cross-checked	• 8 Nutrients: energy, protein, CHO, fats, Fe, Zn, Ca, vit A • 13 FGs (g): cereals, sugars/syrups, starchy roots/tubers, fats and oils, fish/OAAs, meat/poultry, eggs, milk products, legumes/nuts/seeds, fruit, veg, beverages, condiments/spices	• ASEAN FCD	3.0 Reasonable
Hanley-Cook *et al.* (2020) | University (Belgium) & FAO | German government | [41]	WRA *n* = 430 nonpregnant women 15–49 years old, rural | Validation study | 2019 | WFR versus 24 R(1) (list-based) versus 24 R(1) (open recall)	• 24 R: portion tool not stated • WFR: all food and beverages, recipe ingredients weighed by interviewer • Served food for own plate only	• Interview-assisted • RA training • RAs pilot tested • Tablets used for data collection	• Convenience sampling, sample size calculation • Food list adapted to local context • Rainy season only • Tool pre-tested • Randomised 24 R method order • Quality checks	• 10 FGs (%)all starchy foods, beans/peas, nuts/seeds, dairy, flesh foods, egg, DGLveg, vit A-rich F&V, other veg, other fruit	• Not stated	5.0 Very good
Horiuchi *et al.* (2018) | University (Japan) and NGO | NGO (Japan) | [11]	School-age children *n* = 2020 children 6–17 years old | cross-sectional |	• Standard household measuring units (e.g. bag, cup, dish, spoon,	• Interview-assisted • RA training	• Multistage cluster sampling of schools across Cambodia	• 7 Nutrients: energy, protein, CHO, fat, vit A, Fe and Ca • 11 FGs (g):staples, legumes/nuts, vegies/	• ASEAN FCD • SMILING FCD • Developed FIDR	3.5 Good

(Continues)

TABLE 1 (Continued)

Study | Organisation | Funding body |	Population | Study type | Year | DA method	Dietary assessment features			Dietary intake: nutrients or food groups (FG)	Food composition database (FCD)	Quality score
		Portion estimation	Administration	Addressing bias/error			
	2014–2015 | 24 R (1), FR	slice, bowl, or piece) • Picture book; items and portion sizes • No estimates from shared plate		• Non-normal eating days excluded • Adjusted over/ under-reporting	fruit, meat/eggs, fish/ shellfish, milk/ products, fats/oils, sugars, confectionary, condiments, beverages	Nutrition Calculation Database 2013	
Horiuchi *et al.* (2019) | University (Japan) and NGO | NGO (Japan) |[42]	School-age children *n* = 107 children 6–17 years old | validation study | 2014–2015 | 24 R(2), FFQ (over 1 month)	• Portion estimates from median of Horiuchi *et al.*[11]	• Interview-assisted • RA training	• Multistage cluster sampling of schools across Cambodia	• 5 Nutrients:energy, protein, CHO, fat and Ca		5.0 Very good
MoH & FIDR (2017)| University (Japan) & NGO | NGO (Japan) |[18]	School-age children *n* = 2020 children 6–17 years old | cross-sectional | 2014–2015 | 24 R(1), FFQ (over 1 month)	• Picture book of 9 food groups; pictures of actual portions sizes; 130 items	• Interview-assisted • RA training • Quality control measures	• Multistage cluster sampling of schools across Cambodia • Calculated sample size • Tool pre-tested	• 14 Nutrients: energy, protein, vit A, Fe, Ca, dietary fibre, thiamine, riboflavin, niacin, vit C, PO_4, Zn, Na, K, Cu • 6 FGs (frequency): fruit/vegies, fish/ poultry, meat, milk, junk food, softdrink		3.5 Good
In *et al.* (2015) | University (Cambodia)| not stated | [9]	Adults *n* = 941 adults 25–65 years old (36% men/64% women); 3 rural and 1 urban areas | cross-sectional | 2010 | 24 R(2), FFQ	• Colour photos of 3 different portion sizes • Proportions of shared plate estimated	• Interview-assisted	• Convenient sampling, from 4 regions • Seasonality addressed	• 15 FGs (g %):rice, other cereals, starchy roots/tubers, legumes/ nuts/seeds, vegies, fruits, fish/shellfish, meat, eggs, milk, fats/ oils, sugar/ confectionary, alcoholic beverages, nonalcoholic beverages	• Not stated	3.5 Good
Makurat *et al.* (2018) | University (Germany) | German government |[36]	WRA *n* = 158 healthy, non-pregnant women factory workers < 31 years old | RCT Pre versus Post (5 months) Lunch	• Not stated	• Interview-assisted	• List sample • Simple random allocation to intervention • Calculated sample size	• 16 FGs (g):cereals, fish/seafood, flesh meats, vit A-rich veg/ tubers, DGL vegies, other vegies, other fruits, legumes/nuts/ seeds, eggs, milk, white	• Not stated	3.0 Reasonable

TABLE 1 (Continued)

Study | Organisation | Funding body |	Population | Study type | Year | DA method	Dietary assessment features			Dietary intake: nutrients or food groups (FG)	Food composition database (FCD)	Quality score
		Portion estimation	Administration	Addressing bias/error			
	provision versus no-lunch provision | 2015 | 24 R(3)			• Collected skipped meals • Double data entry, cross-checked	roots/tubers, organ meats, vit A-rich fruits sweets, spices/ condiment/beverages, fats/oils		
Menasria *et al.* (2018) | University (Canada), Royal government of Cambodia, NGO | NGO (Canada) |[34]	Child < 5 years old *n* = 360 infants 6–24 months, excluding severe anemia and malnutrition | CRCT, Moringa+NEC versus Cricket+ NEC versus only NEC; 6 months trial | Year not stated | 24 R(3), BFF	• Local utensils • vitamin and mineral supplements intake collected • BM intake (from Dewey & Brown[44])	• Interview-assisted • RA training	• Cluster random sampling • Recall on 2 weekdays + 1 weekend • Data checked by 2 RAs • Tool pre-tested	• 5 Nutrients (satisfaction %):energy, protein, Fe, Zn, vit C	• SMILING FCD, • ASEAN FCD	5.5 Very good
NIS/MoH/DHS (USA) (2015) (CDHS 2014) | Royal Government of Cambodia | Royal government of Cambodia, International aid organisations |[6]	Child <5 years old *n* = 5120 child <5 years old, subset *n* = 2836 child <2 years old | cross-sectional | 2014 | 24 R(1)	• Not stated	• Interview-assisted • RA training	• Computerised random sampling • Representative sample size • Tool pretested • Double data entry • Data quality checks	• 14 FGs (%):infant formula, other milk, other liquid, fortified baby food, food made from grains, vit A-rich F&V, other F&V, food made from roots/ tubers, food made from legumes/nuts, meat/fish/poultry eggs, dairy, any semi-solid/ solid foods	• Not stated	3.5 Good
Reinbott *et al.* (2015/Reinbott *et al.* (2016) (MALIS study) | University (Germany) | FAO, German government |[29,30]	Child <5 years old and WRA Pre: *n* = 743, Post: *n* = 921 Mothers-infant 6–23-month dyads | CRCT, pre post: NEC + agriculture versus agriculture only | 2012–2014 | Mod FFQ(7), 24 R(1), IFP	• Not stated	• Interview-assisted with primary caregiver • RA training • Observation	• 2-stage probability village sampling and randomised households • Tool pretested • Quality controls • Blinded data entry	• 13 FGs (%):grains/ roots/white tubers, flesh foods, other F&V; vit A-rich foods, eggs, legumes/nuts/ seeds, dairy, ASF (meat/fish/poultry/ offal), DGLVeg, vit A-rich roots/tubers, vit A-rich fruits, fats/oils, sugary foods/crisps	• Not stated	4.5 Good

(Continues)

TABLE 1 (Continued)

Study | Organisation | Funding body |	Population | Study type | Year | DA method	Dietary assessment features			Dietary intake: nutrients or food groups (FG)	Food composition database (FCD)	Quality score
		Portion estimation	Administration	Addressing bias/error			
Save the children & USAID (2019) (NOURISH programme) | International NGO | International aid (USA) | [31]	Child <5 years old and WRA n = 2257 women 15 49 years old (n = 500 WRA; n = 397 pregnant women; n = 405 infant 0–5 months; n = 955 child 6–59 months) | Pre and Post, multistratified programme | 2018 | 24 R(1), BFF	• Not stated	• Interview-assisted • Training not stated • Tablets used for data collection (post)	• Random cluster sampling from lists • Calculated sample size proportion to population • Data double translated • Tool pretested • Quality control	Child • 8 FGs (%): grains, animal origin, other F&V, vit A-rich F&V, beans/nut/seeds, eggs, dairy, breastmilk WRA: • 9 FGs (%);grains, flesh food, other F&V, GL vegies, vit A-rich F&V, beans/nut/seeds, eggs, dairy, organ meat	• Not stated	3.5 Good
Schümann *et al.* (2009) |University (Germany) | German government | [35]	Child < 5 years old n = 250 infants 6–24 months; excluding severe anemia and acute malnutrition | DB-CRCT, Fe + Folate versus Fe + micronutrients versus placebo | 2003–2004 | FFQ(7) weekly (20 weeks duration)	• Not stated	• Interview-assisted with mother/caregiver • Trained volunteer health workers	• Computer random sampling by village, adjusted for cluster effects • Calculated sample size	• 8 FGs (frequency):rice porridge, rice, fish (crab, squid, snail, frog), beef, pork, chicken (including ducks and eggs), vegetables and fruits	• Not stated	5.0 Very good
Skau *et al.* (2014) | University (Denmark), Royal government of Cambodia | European Government | [38]	Child < 5 years old n = 78 infants 6–15 months | Cross-sectional Pre and Post RCT: WinFood versus WinFood Lite versus CSB + v CSB + + | 2010 | 24 R (1), R-WFR	• Food pictures • Real food models • Recipe ingredients collected • Weighed estimated portion • Used composite dishes recipes, cooked and weighed (Camb Fish Admin) • BM intake[43]	• Interview-Assisted • RA training	• List sampling - intervention participants • Recalls on all weekdays • Assumption of over-/under-reporting balance	• 33 FGs (g day^{-1} and frequency week^{-1}): • Plaintain, pineapple, lime, papaya, tamarind, fats/oil, white sugar, brown sugar, rice, bread, eggs, lean pork, pork ribs, chicken, beef, large fish, dried shrimp, fermented fish, cabbage, morning glory, tamarind leaves, sponge gourd, wax gourd, tomato, water	• USDA FCD • Vietnamese FCD • Thai FCD	2.5 Reasonable

TABLE 1 (Continued)

Study | Organisation | Funding body |	Population | Study type | Year | DA method	Dietary assessment features: Portion estimation	Dietary assessment features: Administration	Dietary assessment features: Addressing bias/error	Dietary intake: nutrients or food groups (FG)	Food composition database (FCD)	Quality score
					lily, onion, long bean, snacks-candy, snacks-crisp, human milk, formulated complementary foods		
Verbowski *et al.* (2018)/Verbowski (2015) | University (Canada), NGO | University, NGO, International research centre |[32,33]	Child <5 years old and WRA *n* = 421 Child 6 months to 5 years old, *n* = 429 women 18–50 years old | CRCT: Pre and Post, EHFP versus EHFP + F versus no intervention (22 months duration) | 2012 | Pre: 24 R(1), Post: MP 24 R(2)	• Common HH items measured • Graduated food models • F&V: small/medium/large • Collected mixed dishes recipe ingredient weights • Beverages (ml) • Shared plate estimated proportion consumed • BM intake[43]	• Interview-assisted • RA training • Observed interviews • Double recalls for *n* = 300 subset	• Calculated sample size • Parallel cluster sampling of RCT participants • Separate interviewers repeated 24 R • Tool pretested • Quality control • Double data entry • Used 24-VASQ tool (pre); validated 24 R tool[45]	• 14 Nutrients:energy, protein, CHO, fat, Fe, Zn, Ca, vit A, thiamine, riboflavin, niacin, folate, vit B_{12}, water	• ASEAN FCD • Vietnamese FCD • Anderson *et al.*,[7] FCD	4.5 Good
Wallace *et al.* (2014) | University (Canada), International research centre | University (Canada) |[39]	Women/WRA *n* = 67 women 25–75 years old; excluded unwell | cross-sectional + Focus Group | 2011 | Interactive MP 24 R(1)	• Not stated	• Interview-assisted health workers • Training not stated	• Convenience sampling from existing programme • Alerted participants to note portions consumed before recall • Excluded 'non-normal' days • Used validated 24 R tool[45]	• 3 Nutrients: energy, Fe, vit A • 22 key foods based on Fe and vit A collected, not reported in paper	• ASEAN FCD • SMILING FCD • USDA FCD • Thai FCD	2.0 Poor
Yasuoka *et al.* (2020) | University (Japan) | International research centre |[40]	School-age children *n* = 298 children 6–15 years old, with HIV/AIDS | cross-sectional | 2018 | 24 R(1)	• Not stated	• Interview-assisted • Training not stated	• computer-randomised from list of children receiving HIV treatment	• 7 FGs (%):grains/roots/tubers, legumes/nuts, dairy products, flesh foods, eggs, vit A-rich F&V, other F&V	• Not stated	3.0 Reasonable

(Continues)

TABLE 1 (Continued)

Study | Organisation | Funding body |	Population | Study type | Year | DA method	Dietary assessment features: Portion estimation	Administration	Addressing bias/error	Dietary intake: nutrients or food groups (FG)	Food composition database (FCD)	Quality score
			• Tablets used for data collection				

Abbreviations: 24 R, 24-h recall; 24-VASQ, 24-h vitamin A semi-quantitative; agric, agriculture; ASF, animal source foods; BFF, breastfeeding frequency; BM, breastmilk; CRCT, cluster randomised controlled trial; CSB, corn–soy blend; DGL, dark green leafy (vegetables); DA, dietary assessment; EHFP, enhanced home food production; F&V, fruit and vegetables; FCD, food composition database; FFQ, food frequency questionnaire; FG, food groups; FR, food record; HH, household; I&YC, infant and young children; IFP, infant feeding practices; MP, multiple pass; NBF, nonbreastfed; NEC, nutrition education and counselling; NI, nutrient intake; OAAs, other aquatic animals; PBF, partial breastfed; RA, research assistant; R-WFR, retrospective weighed food record; SEA, southeast Asia; WRA, women of reproductive age. *Nutrients*: CHO, carbohydrate; vit A, vitamin A; vit C, vitamin C; Ca, calcium; PO, phosphorus; Na, sodium; K, potassium; Fe, iron; Zn, zinc; Cu, copper.

children over 6 months of age. Reinbott *et al*.[29,30] and the Save the Children's Nourish project[31] collected data on breastfeeding practices for measuring intervention effectiveness, and CDHS 2014[6] collected breastfeeding status and duration data for tracking population behaviour, although there was no reporting of nutrient intakes; hence, they did not apply a breastmilk intake quantification. Schümann *et al*.[35] did not consider breastfeeding in their intervention study.

Dietary assessment methods

All but one study ($n = 14$ studies) used 24-h recalls (24 R),[6,7,9,11,18,29–34,36–42] four studies used food frequency questionnaires (FFQ),[9,18,29,30,35,42] and five studies reported using another method, including weighed food records (WFR) ($n = 4$)[7,37,38,41] or food records ($n = 1$).[11] Four studies indicated collecting breastfeeding frequency data.[6,31,34,37] Of the studies that used 24- R, nine conducted a single recall,[6,7,11,18,29–31,37–40] four collected 2 × 24-h recalls[9,32,33,41,42] and two studies collected 3 × 24-h recalls.[34,36] Four studies indicated using the multipass 24 R method,[7,32,33,39,41] including a fourth pass to record vitamin and mineral supplements. Hanley-Cook compared a list-based (19 food groups) 24 R against an open recall 24 R method, showing higher intake trends with a list-based method.[41] Three 24 R studies indicated intentional recall days selection, either all days of the week,[7] only weekdays,[38] or scheduled non-consecutive weekdays and a weekend day,[34] whereas 'non-normal eating' days were excluded from the data for two studies.[11,39]

Seven studies combined a 24 R with another method, either FFQ ($n = 3$),[9,18,29,30,42] WFR ($n = 4$)[7,37,38,41] or food record ($n = 1$).[11] Except for both Horiuchi *et al*.[42] and Hanley-Cook *et al*.[41] validation studies, these combined methods aimed to enhance the 24 R data collected by adding portion weights (WFR), feeding patterns (observation), frequencies for usual intake or calculating dietary diversity score (DDS).

The reporting period for FFQs varied, with two studies capturing intake from over the past 7 days,[29,30,35] one over the past month[42] and one did not specify a reference time.[9] Only Horiuchi *et al*.[42] described the FFQ development process, selecting 58 items from 24 R, and 10 frequency categories for all items except rice, which used higher frequency categories.

Three studies[7,32,33,39] indicated using the validated dietary intake collection tool of Gibson and Ferguson.[45] Verbowski *et al*.[32,33] used the 24-h vitamin A semi-questionnaire (24-VASQ) tool of De Pee *et al*.[46] for baseline, which is not validated. Four studies[6,31,34,36] indicated that their data collection tool was based on the Cambodian Demographic and Health Survey[6], which has been pretested and repeatedly used for the national population survey; however, the dietary intake section has not undergone validation and reproducibility testing.

TABLE 2 Synthesis of dietary intake patterns by Khmer population group in dietary assessment study review.

Population group	Nutrient intakes assessed	Food intakes assessed
Child≤ 5 years	4 studies[7,32–34,37] • All used 24 R, 1[34] also collected BFF • 7–14 nutrients reported • included energy, protein, vitamin A, calcium, iron and zinc • Mean energy intake 2678–4067 kJ day^{-1} • Mean protein intake range 17.6–31 g day^{-1}, increasing with age • Similar mean intakes for carbohydrate, thiamine, riboflavin and iron across studies • Wider range for vitamin A, niacin, calcium and zinc • 3 studies[7,32–34] collected some V&M supps intake	6 studies[6,29–31,35,37,38] • 5 used 24 R, 2 used FFQ, 2 also used WFR • Food groups range of 8–33 • Highest intake from grain products and fish • Moderate intake of vegetables and snack foods. • For children < 2 years included complementary foods, for example, formulated baby foods, infant formula • 2 studies[31,38] included breastmilk as a food item • Vit A and iron supp intake reported (CDHS)[6]
School-age children 6–17 years old, male and female	1 study[11,18,42] • Used both 24 R and FFQ • Mean energy intake range 5151 kJ day^{-1} (6-year-old girls) to 8715 kJ day^{-1} (16–17-year-old boys) • Intakes increase with age for vitamin A, iron, calcium, vitamin C and zinc • Protein fairly consistent across age groups • Boys intakes higher than girls, especially protein and energy • Intake from 24 R significantly higher than intake from 58-item FFQ for energy and 4 nutrients	2 studies[11,18,40,42] • Both used 24 R, 1 also used FFQ • MoH & FIDR study[18] reported mean daily intake (g); Yasuoka *et al.*[40] % consumption per food group • Highest consumption of staples/grains (650 g, 98%), flesh/meat/fish (116 g, 98%), fruit and vegetables (241 g, 72%–81%) • High intakes of confectionary (29 g day^{-1}), sugars (14 g day^{-1}) and beverages (89 g day^{-1}) • Proportion of daily consumption of junk food (22%) and softdrink (12%); 54% children consume no milk
Women of reproductive age	2 studies[32,33,37] • Both studies used 24 R, 1[37] also used WFR, BFF • Similar mean nutrient intakes, except carbohydrate • Mean energy ranged from 6268 to 8268 kJ day^{-1} • Verbowski *et al.*[32] Verbowski,[33] collected some V&M supps intake at end of study only	4 studies[31,36,37,41] • All used 24 R, 2 WFR and 2 collected BFF • Consistent results; high intake of cereals (369 g), fish (145 g) and vegetables (151 g) • Moderate intake of eggs, fruit, beverages • Low intake of dairy, white roots, organ meats, legumes/nuts • Condiments and fats were prevalent
Adults	1 study[39] (women only) • Used 24 R • Considerably lower medians for vitamin A (249 μg RE) and iron (1.72 mg) than means reported by Bunthang *et al.*[37] and Verbowski *et al.*,[32] Verbowski [33]	1 study[9] (36% men and 64% women) • Used both 24 R and FFQ • Reported 100% participants consume rice daily (average 823 g day^{-1}), over 90% consume vegetables, meat, fish, sugar and condiments. • Intakes generally higher for men except fruit, confectionary, condiments • Higher intakes of most food items, except beverages in wet season

Abbreviations: 24 R, 24-hour recall; FFQ, food frequency questionnaire; FG, food group; FR, food record; N, nutrient; WFR, weighed food record; BFF, breastfeeding frequency; vit A, vitamin A; V&M supps, vitamin and mineral supplements.

Dietary assessment method features

All studies used an interview-assisted method of data collection. Interviewers were field workers, health workers or research assistants, the majority of whom reported having received training from the primary investigators. All interviewers were local Cambodian people fluent in Khmer language and culture. Thirteen studies used traditional pen-and-paper data collection, and three applied computer-assisted data collections through use of a tablet.[31,40,41]

Eight studies indicated using at least one tool for estimating portion size. Tools included standard household utensils volumes ($n = 5$),[7,11,18,32–34,37,42] food models ($n = 4$)[7,32,33,37,38] or food photos ($n = 3$).[9,11,18,38,42] Interviews conducted in participant's home incorporated weighing estimated portions ($n = 5$)[7,32,33,37,38,41] or calibrated household utensils ($n = 1$).[32,33] Shared plate eating was addressed by estimating proportion eaten from a given recipe and weighed ($n = 4$).[9,32,33,37,38]

Randomisation methods included simple randomisation ($n = 1$),[37] cluster sampling ($n = 5$),[11,18,29,30,32–35,42] computer-generated population representation ($n = 1$)[6] and convenience sampling ($n = 3$),[9,39,41] with the remaining five studies[7,31,36,38,40] recruited from lists of

participants from programmes. Table 1 (column 5) reports various techniques for reducing systematic errors for each study, including pre-testing assessment tools ($n = 8$),[6,11,18,29–34,37,41,42] calculating sample size ($n = 7$),[6,11,18,31–33,35,36,41,42] and quality control checks during data collection and data entry ($n = 8$).[6,29–34,36,37,41] Only Horiuchi *et al.*[11] reported adjusting for over-and under-reporting. Seasonal differences were accounted for by duration of data collection over both wet (May to October) and dry (November to April) seasons, evident in five studies.[6,9,11,34,35]

FCDs

Seven studies[7,11,18,32–34,37–39,42] described using a FCD for calculation of nutrient intakes, whereas eight studies[6,9,29–31,35,36,40,41] that reported food group consumption patterns did not analyse nutrient intakes and hence did not use FCD. Nine different FCDs were used to calculate nutrient intakes from dietary intake data collected. The ASEAN FCD[47] (1746-item, 17 food groups, energy and 20 nutrients) was used in six studies,[7,11,18,32–34,37,39,42] and three studies[11,18,34,39,42] also used the 90-item SMILING FCD (14 food groups, 19 nutrients, raw ingredients/foods) developed for Cambodia.[48] Additionally, tailored FCDs were specially developed for three studies[7,11,18,32,33,42] drawing items from ASEAN FCD, SMILING FCD, Thai FCD, Vietnam FCD, Canada FCD and United States Department of Agriculture (USDA) FCD.

Quality assessment

Critical appraisal of study quality was conducted using the EURRECA tool[26] and scores ranged from 2.0 to 5.5 (mean = 3.8, maximum = 7). Four publications achieved the highest quality score of 'very good',[34,35,41,42] nine were 'good',[6,9,11,18,29–33] five rated as 'reasonable'[7,36–38,40] and one was classified as 'poor'.[39] All but one publication ($n = 16$) received a score for sample size over 100, and all scored for interviewer-assisted data collection. Less than half the publications accounted for seasonality in their data collection.[6,9,11,18,34,35] Scores for statistics reflected standard tests for significance, whereas higher scoring publications (>4.5) reported additional statistical analyses. Five publications that measured supplement intake used prompts to assess usage for supplements containing iron, zinc or vitamin A.[6,7,32–34]

DISCUSSION

Despite three decades focused on improving the health and nutritional status of Khmer people to address poverty-driven malnutrition, only 19 papers (15 studies) have been published on individual-level dietary assessment data from dietary intake studies in Cambodia. To our knowledge, this review is the first to synthesise published food and nutrient data and characterise dietary assessment methods used in studies that measured the 'whole diet' of Khmer people living in Cambodia. With strong public health policy and non-government organisations focusing on maternal and child nutrition in Cambodia,[2] it was not surprising that all but one of the included studies were specific to infants, children and women. The dietary assessment methods used to collect dietary intake data were appropriate, but it was not possible to consolidate data because of heterogeneity in outcome measures. Reported food and nutrient intakes of Khmer WRA and children were generally low, although assessing dietary adequacy was not an aim of this review.

Nutrient and food group intake in Cambodia

The low intakes of energy, protein, vitamin A, iron, zinc and calcium reported for both WRA and children across included studies were consistent with findings from studies in other LMICs.[49,50] Although the nutrient intake data were reasonable within and between studies, synthesis of nutrient data was limited by the heterogeneity in nutrients reported, study characteristics, dietary assessment and statistical analysis methods in the small pool of included studies. Although some nutrient intake variability within and between individuals is expected,[51] some variability could be partly attributable to differences in data collection method, FCD, seasonality, local food supply and preparation methods.[52] Seasonality as a quality variable reflects the importance of capturing micronutrient differences that vary across seasons, and considering the distinct wet and dry seasons and inadequate nutrient intakes, this is particularly vital for Cambodia. Differences in specific nutrients may also be partly attributable to each study's aims; for example, studies assessing vitamin A intake would specifically measure vitamin A-rich vegetables and fruits groups using the tailored 24-VASQ tool.[46]

Intakes of protein foods, cereals and grains were high and quite consistent between studies, reflecting Cambodia's staple rice, soup and fish diet; however, intakes reported for vegetables, snack foods, foods containing sugar, condiments and beverages were inconsistent. Different classifications of foods into food groups, numbers of 'groups' of foods reported and differing outcomes measuring dietary diversity or specific food item intakes limited comparison of results between studies. Seasonal differences in food intake were reported by In *et al.*,[9] with higher intakes of rice, starchy roots and vegetables in the wet season, and a higher consumption of all beverages in dry season highlighting the importance of accounting for seasonality in dietary assessment studies. Standardised data collection and reporting of

food groups and nutrients between studies conducted in Cambodia would result in a more robust dietary intake data and facilitate examination of the relationships between diet and health or disease in a range of population groups.

Dietary assessment methodology, methods and study quality

The prominence of the 24-h recall dietary assessment method reflects its versatility for use in different contexts. The standardised data collection approach but open response options are not country-specific, whereas list methods such as a FFQ require considerable adaptation to match country-specific dietary patterns and contexts.[23] Additionally, interviewer-administered 24-h recalls are not literacy-dependent and are less burdensome for the respondent,[51,53] despite being more time-consuming and resource intensive.[23] It is likely that the use of single-day 24-h recalls contributed to variability of reported dietary intake in included studies, with at least 3 days of dietary intake and a four- or five-stage multiple-pass process recommended for robust data.[54,55] To further enhance accuracy, multiple-pass methods need modifying to be country-specific, with probes and prompts tailored to the local food culture. Overall, methodological details for 24-h recall and FFQ methods were lacking, which limited data generalisability of study findings.

Portion size estimation tools aim to reduce potentially large measurement errors of quantifying food portions by participants[52,56]; however, appropriateness and validity of aids also need to be considered for dietary assessment study objectives and participant type.[57] With all studies except one[39] using portion estimation tools that quantified nutrient intake, and the majority using a combination of aids, it would appear the process of estimating portions was appropriate. Individual-level portion estimation is complicated by communal eating, with specific methods to collect dietary intake from shared plates needed for valid intake estimation.[20] It is common in Cambodian households for meals to involve multiple people portioning or eating food from one or two central dishes (personal communication). Although shared plate eating was not explicitly reported, studies estimated the proportion consumed from mixed dishes recipes or weighed an estimated portion retrospectively during 24 R.[7,9,32,33,37] Simple but effective methods for collecting individual-level intake of mixed dishes from shared plates would increase the accuracy of dietary intake estimation in LMIC.[20] Other approaches for improving participant recall particularly for LMICs include pre-recall day group training on portion size estimation using picture charts, household items and salted replica food models.[52,56]

Dietary assessment is prone to systematic errors, including risk of selection bias, observation and recall biases. Strategies reported in included studies to reduce systematic errors included randomisation methods to reduce selection bias, statistical sampling, varying data collection days, using different interviewers for repeat recalls to mitigate recall bias[32,33] and excluding days of non-normal intake to reduce risk of analytic errors.[11,39] Using dietary assessment tools validated for use in the LMIC context is another way to reduce systematic errors in dietary intake data collection.[23] The interactive validated tool for assessing iron and zinc intake used in three included studies was reported as validated for use in developing nations,[45] although it has not been validated for the Cambodian setting. Although tools such as 24-VASQ[46] and CDHS[6] had been pre-tested and adjusted to the Cambodian context, none have been systematically tested and validated against another 'gold standard' method.[58]

Dietary intake data in all included studies were collected by trained local Khmer interviewers. This is likely to have enhanced data quality as personal interviews are reported to increase acceptability to the interviewee and the accuracy and quality of data collected,[26] especially when conducted by locals with their intrinsic understanding of cultural food and eating patterns.[51] Although the Food and Agriculture Organization (FAO) recommends that nutritionists and dietitians are preferred field workers in dietary assessment studies,[51] there is limited formal training of nutrition specialists in Cambodia. Until a reputable nutrition-based education programme is established in Cambodia, training suitably skilled Khmer workers to use study-specific tools and administer interviews is more feasible and appropriate than training foreign dietitians to speak Khmer and recognise Cambodia foods, recipes and cooking methods. In this review, quality control measures such as observation, checking data entry and pilot testing were used to increase accuracy and reduce systematic errors were reported in most studies.

The International Network of Food Data Systems (INFOODS)[59] was established in 1984 to address the need for improved quality and availability of reliable food composition data, but limited investment in FCD in LMICs continues to be a major gap in dietary assessment research.[23] A comprehensive Cambodian-specific FCD was not reported in any studies included in this review, introducing substantial risk of systematic analysis errors. Nutrient data for dietary intake analyses were reported as being sourced from FCDs of other countries, not only primarily South-East Asian, but also Western and European countries. The FCD most accessed was ASEAN, a 1746-item database of foods from five neighbouring Asian countries developed in collaboration with INFOODS.[47] ASEAN contains very few mixed dishes and no Cambodian-specific foods, and the absence of Khmer translations limits application to Cambodian studies. The versatility of the 90-item Khmer-specific SMILING FCD is limited because it only contains

individual raw ingredients, not cooked foods or mixed dishes.[48] Studies in this review either used ASEAN only or both of these FCDs but also sourced items from Thai, Vietnamese and USDA FCDs.

This review highlights that the risks of systematic errors in dietary assessment are exacerbated in LMICs, but can be mitigated by adapting evidence-based approaches that suit the cultural context. This was reinforced by the overall 'good' study quality rating of included studies, with sample size and interviewer-assisted data collection being well reported. Improvements include accounting for seasonality in data collection, reporting of statistical analysis and reporting of supplementation. The high weighting of supplements in EURRECA reflects their considerable impact on micronutrient intake and EURRECA's micronutrient focus.[26,60] The only vitamin or mineral supplement intakes reported in dietary assessment studies in this review were iron,[34] vitamin A and zinc supplements for children,[6] as well as iron supplements for mothers.[6,31] Supplement intake was likely to be collected in studies that used the multiple-pass method,[7,32,33,39] but nutrient intakes from supplements were not clearly reported. The quality of reporting and accuracy of micronutrient intake in dietary assessment could be improved if supplement intakes were routinely queried within assessment methods and incorporated, using prompts or probes such as the multiple pass 24 R method.[54,55]

Limitations

The complexity of accurately assessing and analysing dietary intake at an individual level in Cambodia contributes to some of the limitations reported in this review. It is also likely that the dietary assessment methods and methodologies used in studies may have been rigorous but were not fully or explicitly reported in articles. Additional limitations are attributable to broader societal and socio-demographic Khmer traits. For example, Khmer people may misreport dietary intake if they feel shame about eating certain foods or perceive that their reported food intake will influence taxation or provision of food supplies. Customs such as fasting, food taboos, farming duties and seasonal differences impact data collection planning and process. Local food habits such as foraging, use of medicinal and home-grown Cambodian foods and unique cultural recipes impact on selection of appropriate items from FCDs. These limitations need to be considered and accounted for, where possible, in dietary assessment research in Cambodia and other LMICs.[58]

There are no tailored tools for measuring quality of dietary assessment studies conducted in LMICs, despite quality being identified as problematic.[24] The EURRECA study quality assessment tool chosen for this review was selected from five possible tools scrutinised for suitability. Tools were excluded if they were designed for interventions only[61], were for FFQs only[62], were reporting on guidelines or were not recommended for appraising quality.[25,63] Although the three-step EURRECA tool was designed for validation studies, it was determined that step one, consisting of scoring five variables, could be applied to non-validation dietary assessment studies as an indication of quality. The lack of suitable quality assessment tools for dietary assessment studies highlights an opportunity to develop one through expanding EURRECA to add variables such as tool pretesting, reference to a recognised FCD, study duration, quality control measures and intake outcomes reported. This comprehensive description of the methodology would allow for study reproducibility and consolidation of data. A draft checklist in the Supporting information (Table S5) collates variables from these tools as a suggested resource, requiring thorough testing and validating in order to recommend it as a reliable tool.

Implications for future research

The current review has identified priority areas for further research and development to facilitate improved nutrition surveillance, policy planning and promotion in Cambodia. With assistance from international dietary assessment research groups, these recommendations include:

1. Develop a best practice protocol for conducting dietary assessment studies that is appropriate for the Cambodian context with the first step being to review current guidelines for conducting dietary assessment studies from reputable sources,[45,51,53,55,58,64] then making adjustments for the specific cultural context in Cambodia. A companion checklist for assessing quality of future studies could also be developed.
2. Establish a core minimum data set for reporting dietary intake, including data that are accessible to the wider Asian and international community. Referring to STROBE-nut guidelines would improve standards of reporting,[25] and FAO/WHO's Global Individual Food Consumption Tool (GIFT) would address data access.[65]
3. Establish a Cambodian-specific FCD or expand the existing ASEAN FCD to include commonly consumed food items from different Asian countries or cuisine types, particularly mixed dishes and fortified condiments and sauces.
4. Train and support a workforce of local nutritionists or nutrition researchers to conduct dietary assessment studies and analyse data at an international standard, at the same time as advocating at a national level for maximum policy impact.
5. Use the resources from points (1) to (4) to establish a national nutrition surveillance programme for all

Cambodian population groups (infants, children, adolescents, pregnant women, men and women adults and older-aged adults). This could be incorporated into the 5-yearly CDHS, along with a substudy for validation of tools of specific population groups or key problem nutrients.

6. Generate opportunities for global agency partners to support (funds and expertise) these high-cost strategic initiatives, collaboratively guiding and building capacity with Cambodian professionals.

CONCLUSIONS

Population dietary and nutrient intakes in Cambodia remain suboptimal despite considerable and intentional efforts, particularly towards improving micronutrient intake and preventing malnutrition. This review has identified that global agencies with international dietary assessment expertise need to align or partner with government policy and honour country-specific cultural contexts to facilitate collection and analysis of dietary intake data in LMICs such as Cambodia. Individual-level dietary assessment could be strengthened by standardised reporting, use of consistent nutrient and food group measures, developing a Cambodia-specific FCD, having a competent trained nutrition research workforce, and productive global support and funding. Accurate, specific dietary intake data would inform future nutrition interventions, policy and nutrition surveillance in Cambodia as a key strategy to target improvement in population level nutrition-related health and wellbeing.

AUTHOR CONTRIBUTIONS

Janelle L. Windus is the lead author, primary reviewer, and conducted searches, data extraction and analysis, as well as manuscript preparation and writing. Kerith Duncanson is a secondary reviewer, advising design, data analysis and interpretation, and performed manuscript revision. Tracy L. Burrows is a secondary reviewer, advising design, data analysis and interpretation, and performed manuscript revision. Clare E. Collins is review advisor on design and interpretation, and performed manuscript revision. Megan E. Rollo is a secondary reviewer, advising design, data analysis and interpretation, and performed manuscript revision. All authors contributed to the review design and manuscript drafting, and critically reviewed and approved the final version of the manuscript submitted for publication.

ACKNOWLEDGEMENTS

The authors thank Soriah Harvey and Samantha Stewart for assistance in cross-checking the extraction and quality scoring. This research received no specific grant from any funding agency, commercial or not-for-profit sectors. Megan E. Rollo is supported by funding from the Hunter Medical Research Institute (Ref HMRI 1661). Open access publishing facilitated by The University of Newcastle, as part of the Wiley - The University of Newcastle agreement via the Council of Australian University Librarians.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

ETHICS STATEMENT

Ethics approval was not required for a review of published studies.

TRANSPARENCY DECLARATION

The lead author affirms that this manuscript is an honest, accurate and transparent account of the study being reported. The reporting of this work is compliant with PRISMA guidelines. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned have been explained.

ORCID

Janelle L. Windus http://orcid.org/0000-0003-0108-9505
Kerith Duncanson http://orcid.org/0000-0001-5525-6589
Tracy L. Burrows http://orcid.org/0000-0002-1431-7864
Clare E. Collins http://orcid.org/0000-0003-3298-756X
Megan E. Rollo http://orcid.org/0000-0003-1303-2063

REFERENCES

1. Public Health Development. Profile of health and its determinants in Cambodia. United Kingdom: NHS South Central Strategic Health Authority; 2008.
2. Council for Agriculture and Rural Development (CARD) and Technical Working Group for Social Protection and Food Security and Nutrition. The second national strategy for food security and nutrition 2019-2023. Phnom Penh, Cambodia: Ministry of Health; 2019.
3. Asian Development Bank. Cambodia country poverty analysis - December 2011. Philippines: Asian Development Bank; 2012.
4. Roos N, Ponce MC, Doak CM, Dijkhuizen M, Polman K, Chamnan C, et al. Micronutrient status of populations and preventive nutrition interventions in South East Asia. Matern Child Health J. 2019;23:29–45. https://doi.org/10.1007/s10995-018-2639-2
5. McDonald CM, McLean J, Kroeun H, Talukder A, Lynd LD, Green TJ. Correlates of household food insecurity and low dietary diversity in rural Cambodia. Asia Pac J Clin Nutr. 2015;24:720–30. https://doi.org/10.6133/apjcn.2015.24.4.14
6. National Institute of Statistics. Cambodian Demographic & Health Survey (CDHS) 2014; included Cambodian Micronutrient Survey (CMNS-2014). Phnom Penh, Cambodia: Ministry of Health, Cambodia; 2015.
7. Anderson VP, Cornwall J, Jack S, Gibson RS. Intakes from non-breastmilk foods for stunted toddlers living in poor urban villages of Phnom Penh, Cambodia, are inadequate. Matern Child Nutr. 2008;4:146–59. https://doi.org/10.1111/j.1740-8709.2007.00120.x

8. Kuong K, Tor P, Perignon M, Fiorentino M, Chamnan C, Berger J, et al. Multi-micronutrient fortified rice improved serum zinc and folate concentrations of Cambodian school children. A double-blinded cluster-randomized controlled trial. Nutrients. 2019;11:2843. https://doi.org/10.3390/nu11122843
9. In S, Lambre C, Camel V, Ouldelhkim MRegional and seasonal variations of food consumption in Cambodia. Mal J Nutr. 2015; 21:167–78.
10. National Institute of Statistics. Food security trend analysis report; Cambodia Socio-Economics Surveys (CSES) 2004 & 2009. Phnom Penh, Cambodia, Ministry of Planning; 2011.
11. Horiuchi Y, Kusama K, Kanha S, Yoshiike N, FIDR research t. Urban-rural differences in nutritional status and dietary intakes of school-aged children in Cambodia. Nutrients. 2018;11:14. https://doi.org/10.3390/nu11010014
12. Helen Keller International Cambodia. An overview of nutrition sector activities in Cambodia. Phnom Penh: Helen Kellar International; 2002.
13. Windus JL, Burrows TL, Duncanson K, Collins CE, Rollo ME. Scoping review of nutrition intervention and dietary assessment studies in Khmer populations living in Cambodia. J Hum Nutr Diet. 2021;34:953–68. https://doi.org/10.1111/jhn.12932
14. National Nutrition Program. National nutrition strategy: 2009-2015. Phnom Penh, Cambodia: Ministry of Health; 2009.
15. National Nutrition Program. Fast track road map for improving nutrition: 2014-2020. Phnom Penh, Cambodia: National Maternal and Child Health Centre, Ministry of Health; 2014.
16. The World Bank. Cambodia Nutrition Project (P162675). World Bank Group; 2019.
17. United NationsUnited Nations sustainable development goals. UN; 2015 [cited 2021 Jul 12]. Available from: https://sdgs.un.org/
18. Ministry of Health, National Nutrition Program, and Foundation of International Development Relief (FIDR). Development of recommended dietary allowance and food based dietary guidelines for school aged children in Cambodia. Phnom Penh, Cambodia. 2017.
19. Burlingame B. GEMS/food total diet studies: report of the 2nd International workshop on Total Diet Studies. Brisbane, Australia: World Health Organisation; 2002.
20. Burrows T, Collins C, Adam M, Duncanson K, Rollo M. Dietary assessment of shared plate eating: a missing link. Nutrients. 2019; 11(4):789. https://doi.org/10.3390/nu11040789
21. deBruyn J, Ferguson E, Allman-Farinelli M, Darnton-Hill I, Maulaga W, Msuya J, et al. Food composition tables in resource-poor settings: exploring current limitations and opportunities, with a focus on animal-source foods in sub-Saharan Africa. Br J Nutr. 2016; 116:1–11. https://doi.org/10.1017/S0007114516003706
22. Hulshof P, Doets E, Seyha S, Bunthang T, Vonglokham M, Kounnavong S, et al. Food composition tables in Southeast Asia: the contribution of the SMILING project. Matern Child Health J. 2019; 23(Suppl 1):46–54. https://doi.org/10.1007/s10995-018-2528-8
23. Coates JC, Colaiezzi BA, Bell W, Charrondiere UR, Leclercq C. Overcoming dietary assessment challenges in low-income countries: technological solutions proposed by the International Dietary Data Expansion (INDDEX) Project. Nutrients. 2017;9(3):289. https://doi.org/10.3390/nu9030289
24. Glasziou P, Altman DG, Bossuyt P, Boutron I, Clarke M, Julious S, et al. Reducing waste from incomplete or unusable reports of biomedical research. Lancet. 2014;Jan 18;383:267–76. https://doi.org/10.1016/S0140-6736(13)62228-X
25. Lachat C, Hawwash D, Ocké MC, Berg C, Forsum E, Hörnell A, et al. I. Strengthening the reporting of observational studies in epidemiology – nutritional epidemiology (STROBE-nut): an extension of the STROBE statement. Nutrition Bulletin. 2016;41: 240–51. https://doi.org/10.1111/nbu.12217
26. Serra-Majem L, Frost Andersen L, Henríque-Sánchez P, Doreste-Alonso J, Sánchez-Villegas A, Ortiz-Andrelluchi A, et al. Evaluating the quality of dietary intake validation studies. Br J Nutr. 2009;102:S3–9. https://doi.org/10.1017/S0007114509993114
27. den Hartog AP, vanStaveren WA, Brouwer ID. Food habits and consumption in developing countries: manual for field studies. Wageningen, the Netherlands: Wageningen Academic Publishers; 2006.
28. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and rxplanation. Ann Intern Med. 2018;169: 467–73. https://doi.org/10.7326/M18-0850
29. Reinbott A, Kuchenbecker J, Herrmann J, Jordan I, Muehlhoff E, Kevanna O, et al. A child feeding index is superior to WHO IYCF indicators in explaining length-for-age Z-scores of young children in rural Cambodia. Paediatr Int Child Health. 2015;35:124–34. https://doi.org/10.1179/2046905514Y.0000000155
30. Reinbott A, Schelling A, Kuchenbecker J, Jeremias T, Russell I, Kevanna O, et al. Nutrition education linked to agricultural interventions improved child dietary diversity in rural Cambodia. Br J Nutr. 2016;116:1457–68. https://doi.org/10.1017/S0007114516003433
31. Save the Children & USAID. NOURISH project endline survey report. Phnom Penh: Save the Children & USAID; April 2019.
32. Verbowski V, Talukder Z, Hou K, Sok Hoing L, Michaux K, Anderson V, et al. Effect of enhanced homestead food production and aquaculture on dietary intakes of women and children in rural Cambodia: a cluster randomized controlled trial. Matern Child Nutr. 2018;14:e12581. https://doi.org/10.1111/mcn.12581
33. Verbowski VC. *The effect of plant-based homestead food production with and without small-scale aquaculture on dietary intake of women farmers and their children in Prey Veng, Cambodia (thesis)* [Degree of Master of Science]. Vancouver: University of British Columbia; 2015.
34. Menasria L, Blaney S, Main B, Vong L, Hun V, Raminashvili D, et al. Mitigated impact of provision of local foods combined with nutrition education and counseling on young child nutritional status in Cambodia. Nutrients. 2018;10(10):1450. https://doi.org/10.3390/nu10101450
35. Schümann K, Longfils P, Monchy D, vonXylander S, Weinheimer H, Solomons NW. Efficacy and safety of twice-weekly administration of three RDAs of iron and folic acid with and without complement of 14 essential micronutrients at one or two RDAs: a placebo-controlled intervention trial in anemic Cambodian infants 6 to 24 months of age. Eur J Clin Nutr. 2009; 63:355–68. https://doi.org/10.1038/sj.ejcn.1602930
36. Makurat J, Kretz EC, Wieringa FT, Chamnan C, Krawinkel MB. Dietary diversity in Cambodian garment workers: the role of free lunch provision. Nutrients. 2018;10(8):1010. https://doi.org/10.3390/nu10081010
37. Bunthang T, Nam S, Phen C, Chhantana P, Net E. Enhancing food security and household nutrition of women and children with a focus on nutrient dense commonly consumed fish from capture fisheries and aquaculture in Cambodia, part I. Food and nutritional consumption survey: women and preschool-age children in Cambodia. Enhanced Trade and Investment for Global Fishery Markets. 2014;22–50.
38. Skau JK, Bunthang T, Chamnan C, Wieringa FT, Dijkhuizen MA, Roos N, et al. The use of linear programming to determine whether a formulated complementary food product can ensure adequate nutrients for 6- to 11-month-old Cambodian infants. Am J Clin Nutr. 2014;99:130–8. https://doi.org/10.3945/ajcn.113.073700
39. Wallace LJ, Summerlee AJ, Dewey CE, Hak C, Hall A, Charles CV. Women's nutrient intakes and food-related knowledge in rural Kandal province, Cambodia. Asia Pac J Clin Nutr. 2014;23:263–71. https://doi.org/10.6133/apjcn.2014.23.2.02
40. Yasuoka J, Yi S, Okawa S, Tuot S, Murayama M, Huot C, et al. Nutritional status and dietary diversity of school-age children

living with HIV: a cross-sectional study in Phnom Penh, Cambodia. BMC Public Health. 2020;20:1181.
41. Hanley-Cook GT, Tung JYA, Sattamini IF, Marinda PA, Thong K, Zerfu D, et al. Minimum dietary diversity for women of reproductive age (MDD-W) data collection: validity of the list-based and open recall methods as compared to weighed food record. Nutrients. 2020;12:2039.
42. Horiuchi Y, Kusama K, Sar K, Yoshiike N. Development and validation of a food frequency questionnaire (FFQ) for assessing dietary macronutrients and calcium intake in Cambodian school-aged children. Nutr J. 2019;18:11. https://doi.org/10.1186/s12937-019-0437-3
43. Brown K, Dewey K, Allen L. Complementary feeding of young children in developing countries: a review of current scientific knowledge. Geneva: World Health Organization; 1998.
44. Dewey KG, Brown KH. Update on technical issues concerning complementary feeding of young children in developing countries and implications for intervention programs. Food & Nutr Bull. 2003;24(1).
45. Gibson RS, Ferguson EL. An interactive 24-hour recall for assessing the adequacy of iron and zinc intakes in developing countries. Harvest Plus. Washington DC: International Life Sciences Institute; 2008.
46. De Pee S, Bloem MW, Halati S, Soekarjo D, Sari M, Martini E, et al. 24-VASQ method for estimating vitamin A intake: reproducibility and relationship with vitamin A status. Report of the XIX International vitamin A Consultative Group meeting. Washington, DC: International Life Sciences Research Foundation; 1999.
47. Institute of Nutrition, Mahidol UniversityASEAN food composition database, Electronic version. 2014 [cited 2021 Aug 6]. Available from: http://www.inmu.mahidol.ac.th/aseanfoods/composition_data.html
48. Sok SSMILING food composition table for Cambodia. Phnom Penh: Ministry of Agriculture, Forestry and Fisheries of Cambodia, Department of Fisheries Post-Harvest Technologies and Quality Control, Ministry of Health, Cambodia and National Maternal and Child Health Centre; 2013.
49. Ratsavong K, vanElsacker T, Doungvichit D, Siengsounthone L, Kounnavong S, Essink D. Are dietary intake and nutritional status influenced by gender? The pattern of dietary intake in Lao PDR: a developing country. Nutr J. 2020;19(1):31. https://doi.org/10.1186/s12937-020-00545-9
50. Lee SE, Talegawkar SA, Merialdi M, Caulfield LE. Dietary intakes of women during pregnancy in low- and middle-income countries. Public Health Nutr. 2013;16:1340–53. https://doi.org/10.1017/S1368980012004417
51. Food and Agriculture Organization of the United Nations. A resource guide to method selection and application in low resource settings. Rome, Italy: Food and Agriculture Organization of the United Nations; 2018.
52. Gibson R, Charrondiere UR, Bell W. Measurement errors in dietary assessment using self-reported 24-hour recalls in low-income countries and strategies for their prevention. Adv Nutr. 2017;8:980–91. https://doi.org/10.3945/an.117.016980
53. Institute of Medicine. Dietary risk assessment in the WIC program. Washington, DC: Committee on Dietary Risk Assessment in the WIC Program; 2002.
54. Steinfeldt L, Anand J, Murayi T. Food reporting patterns in the USDA automated multiple-pass method. Procedia Food Sci. 2013;2:145–56. https://doi.org/10.1016/j.profoo.2013.04.022
55. Gibson RS. Principles of nutrition assessment. 2nd ed.New York: Oxford University Press; 2005.
56. Sharma V, Chadha R. Effectiveness of food portion size estimation aids for diet assessment: A systematic review. Int J Food Sci Nutr Diet. 2017;2:106–12.
57. deVlieger NM, Weltert M, Molenaar A, McCaffrey TA, Rollo ME, Truby H, et al. A systematic review of recall errors associated with portion size estimation aids in children. Appetite. 2020;147:104522. https://doi.org/10.1016/j.appet.2019.104522
58. Cameron ME, Van Staveren WA. Manual on methodology for food consumption studies. Oxford: Oxford University Press; 1988.
59. International Network of Food Data Systems (INFOODS). FAO. [2021 cited Oct 02]. Available from: www.fao.org/infoods
60. Henríquez-Sánchez P, Sánchez-Villegas A, Doreste-Alonso J, Ortiz-Andrellucchi A, Pfrimer K, Serra-Majem L. Dietary assessment methods for micronutrient intake: a systematic review on vitamins. Br J Nutr. 2009;102: S10–37. https://doi.org/10.1017/S0007114509993126
61. Academy of Nutrition and Dietetics. Evidence analysis manual: steps in the academy evidence analysis process. Chicago, USA: Academy of Nutrition and Dietetics; 2016.
62. Dennis LK, Snetselaar LG, Nothwehr FK, Stewart RE. Developing a scoring method for evaluating dietary methodology in reviews of epidemiologic studies. J Am Diet Assoc. 2003;103:483–7. https://doi.org/10.1053/jada.2003.50081
63. Schulz KF, Altman DG, Moher D, CONSORT Group. CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials. BMC Med. 2010;8:18. https://doi.org/10.1186/1741-7015-8-18
64. Cade JE, Warthon-Medina M, Albar S, Alwan NA, Ness A, Roe M, et al. DIET@NET: Best Practice Guidelines for dietary assessment in health research. BMC Med. 2017;15:202. https://doi.org/10.1186/s12916-017-0962-x
65. Leclercq C, Allemand P, Balcerzak A, et al FAO/WHO GIFT (Global Individual Food consumption data Tool): a global repository for harmonised individual quantitative food consumption studies. In: Proc Nutr Soc. 78. 2019. p. 484–95. https://doi.org/10.1017/S0029665119000491

AUTHOR BIOGRAPHIES

Mrs Janelle L. Windus, BappSci (F&N), MND. Janelle's experience includes hospital and private clinical dietetics, university-based research on pregnancy and infant nutrition programmes, and dietary assessment in Cambodia, on which her current PhD studies is based.

Dr Kerith Duncanson, PhD. Kerith's diverse career includes 30 years of nutrition and dietetics across public and private sectors and Research Dietitian for University of Newcastle, with her PhD investigating child feeding practices.

Professor Tracy L. Burrows, PhD. Tracy is a Professor in Nutrition and Dietetics at University of Newcastle and researcher at Hunter Medical Research Institute, focusing on dietary assessment, eating behaviors, weight management and addictive eating.

Laureate Professor Clare E. Collins, PhD. Clare is a Fellow of the Australian Academy of Health and Medical Sciences, Nutrition Society of Australia and Dietitians Australia. Her research focusses on personalised nutrition technologies/programmes evaluating impact on diet-related health across life stages and chronic disease.

Dr Megan E. Rollo, PhD. As Research Fellow in Nutrition and Dietetics within the School of Health Sciences at University of Newcastle, Megan has investigated technology-assisted dietary assessment and personalised behavioral nutrition interventions.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Windus JL, Duncanson K, Burrows TL, Collins CE, Rollo ME. Review of dietary assessment studies conducted among Khmer populations living in Cambodia. J Hum Nutr Diet. 2022;35:901–918. https://doi.org/10.1111/jhn.13011

Received: 3 June 2021 | Accepted: 6 December 2021

DOI: 10.1111/jhn.12977

JHND Journal of Human Nutrition and Dietetics | BDA The Association of UK Dietitians

Factors associated with food choice among long-term weight loss maintainers

Jacob Young[1] | **Suzanne Phelan**[1] | **Noemi Alarcon**[1] | **James Roake**[1] | **Chad D. Rethorst**[2] | **Gary D. Foster**[3,4]

[1]Department of Kinesiology & Public Health, the Center for Health Research, California Polytechnic State University, San Luis Obispo, California, USA

[2]Texas A&M Agrilife Research, Dallas, Texas, USA

[3]WW International, Inc., New York, New York, USA

[4]Perelman School of Medicine, Center for Weight and Eating Disorders, University of Pennsylvania, Philadelphia, Pennsylvania, USA

Correspondence

Suzanne Phelan, Department of Kinesiology & Public Health, the Center for Health Research, California Polytechnic State University, 1 Grand Ave, San Luis Obispo, CA 93407-0386, USA.
Email: sphelan@calpoly.edu

Funding information

WW International, Inc.; The William and Linda Frost Fund at California Polytechnic State University

Abstract

Background: The present study aimed to examine motivations for food choice among long-term weight loss maintainers (WLM) in a widely used commercial weight management program.

Methods: A cross-sectional study was employed where determinants of food choice were measured in the USA using validated scales: Food Choice Questionnaire, Consideration of Future Consequences, and Eating in the Absence of Hunger. Participants were 3806 WLM following a commercial weight management program (WW International, Inc.) who had maintained a weight loss ≥ 9.1 kg (mean 24.7 kg) for 3.3 years and had a body mass index (BMI) of 27.6 kg m^2. A control group of weight stable individuals with obesity (controls; $n = 519$) had a BMI of 38.9 kg m^2 and a weight change < 2.3 kg over the previous 5 years.

Results: WLM vs. controls made food decisions more based on health (18.9 vs. 16.3; $\eta_p^2 = 0.052$) and weight control (9.9 vs. 7.5; $\eta_p^2 = 0.16$) and less based on price (8.4 vs. 9.1; $\eta_p^2 = 0.10$). WLM also scored higher than controls with respect to considering future consequences of behaviours (44.3 vs. 38.4; $\eta_p^2 = 0.060$) and reported less external eating in the absence of hunger (7.1 vs. 7.5; $\eta_p^2 = 0.058$). Standard canonical coefficients indicated that making food choices based on weight (0.717) with less value placed on price (−0.33) and greater consideration of future consequences (0.262) contributed independently and most (overall $r = 0.593$; $p = 0.0001$) to discriminating WLM from controls.

Conclusions: In a widely used commercial weight management program, successful WLM reported food decisions based more on weight and less on price and considered future consequences of current behaviours.

KEYWORDS

dietary patterns, future orientation, motivations, weight loss maintenance

Key points

- Long-term weight loss maintainers consume a diet that is low in calories and micronutrient rich, although the diverse factors that govern these food choices remain unclear.
- The present study examined diverse factors associated with food choice among weight loss maintainers in a widely used commercial weight management program (WW International, Inc.) compared to weight stable individuals with obesity ("controls").

- Weight loss maintainers more than controls made food decisions based on health and weight control and less based on price. Both groups scored similarly in the role of convenience, mood, sensory appeal, natural content, familiarity and ethical concerns.
- Weight loss maintainers were overall more likely to consider future consequences.
- In a widely used commercial weight management program (WW International, Inc.), successful weight loss maintainers reported food decisions based more on weight and health and less on price. They also considered future consequences of current behaviours.

INTRODUCTION

Long-term weight loss maintainers (WLM) consume a low-energy dense diet that is micronutrient rich.[1] Successful WLM also report high dietary consistency, tending to eat the same foods during the week as on weekends and during the holidays vs. non-holiday times.[2] Moreover, high levels of cognitive restraint, defined as conscious control overeating, have been extensively reported among WLM.[3] Although the content, consistency, and ability to restrict eating have been studied among WLM, other behavioural and attitudinal factors that may influence food choice have received less attention.

Prior research in general populations has shown that beliefs about food, health, weight, food familiarity and perceived sensory properties, current mood, ethical concerns, and food price may shape food choices.[4–7] Moreover, an ability to focus on the future[8] and resist eating in response to tempting food cues[9–11] have been identified as promising strategies for weight management. However, research to date generally has been limited by a restricted range of measures, lack of measurement of weight status, and a narrow range of populations, such as consumers,[7] employees,[9] undergraduate students[8] or convenience[6] samples. No known research has comprehensively surveyed the factors that relate to the food choices among people with varying weight statuses, including among long-term WLM. The scientific report for the 2020 Dietary Guidelines Advisory Committee[12] recognised the need for more research to better understand not only on what people choose to eat, but also the social, economic, and environmental factors that shape dietary patterns. A comprehensive understanding of the diverse factors that may influence eating decisions is critical for informing the development of effective interventions that aim to modify unhealthy dietary patterns and promote long-term successful weight control.

The present study aimed to examine the factors that distinguish food choices among long-term WLM in a widely used a commercial weight management program (WW International, Inc.) compared to weight stable individuals with obesity. The study hypothesised that WLM would report food choices that were more motivated by health and weight-related factors and less motivated by responses to palatable food cues than weight stable individuals with obesity. WLM were also hypothesised to score higher on future orientation then weight stable individuals with obesity.

METHODS

Design

The WW Success Registry (WWSR) is an observational study of individuals who have lost weight in the WW International, Inc. program and were successful at long-term (≥1 year) maintenance of substantial (≥9.1 kg) weight loss.[1,13,14] In this cross-sectional study, long-term WLM following the weight management program (WW) are compared with weight stable individuals with obesity ("controls") to distinguish the factors associated with successful maintenance of weight loss.

Participants and eligibility

Procedures were approved by the Institutional Review Board, and all participants provided informed consent electronically via Research Electronic Data Capture (REDCap).

Weight loss maintainers

Prospective WLM were recruited through an email sent by WW to members who had reported a loss of ≥9.1 kg >1 year ago when following WW. Interested individuals were referred to the study website hosted by the university for online screening, consent, and enrollment. Eligibility was based on self-reported weight, height, weight change, and duration of weight loss. To be eligible for enrollment, individuals were aged ≥ 18 years and had maintained a >9.1 kg loss from WW entry for ≥1 year. The criterion 9.1 kg was selected to approximate a clinically significant 10% weight loss,[15] assuming a starting weight of 90 kg among people entering WW and other weight loss programs.[16] Use of an absolute weight

loss value was also intended to simplify messaging for recruitment and eligibility screening and has been used successfully in the National Weight Control Registry.[17]

Weight stable individuals with obesity

Weight stable individuals with obesity were recruited through local and national advertising channels, including Facebook, ResearchMatch.org, Amazon, Mechanical Turk, and via the Academic Center for Health Research registry. Interested individuals were referred to the study website hosted by the university for online screening, consent, and enrollment. Eligibility was based on self-report and included age ≥ 18 years, with a body mass index (BMI) > 30 kg m^{-2} and reported weight stability (within 2.3 kg) for at ≥ 5 years prior to enrollment.[18] Control participants were not currently enrolled in WW. Control participants were provided 1 month of the WW online program (WW Digital) free of charge after completion of the survey.

Measures

All measures were administered online via REDCap immediately after consent. All participants were asked standard demographic information (age, education level, income, marital status) and details about weight history (age of onset of overweight, maximum lifetime weight), as well as current weight and height. The validity of self-reported weight history has been established previously.[3] Also, self-reported weights have been shown to correlate strongly with measured weights.[19]

The Food Choice Questionnaire (FCQ)[20] was used to measure diverse factors that influence food decisions, including subscales for health, mood, convenience, sensory appeal, natural content, price, weight control, familiarity, and ethical concern. Participants were asked to rate the importance of diverse determinants of food choice by responding to the prompt, "It is important to me that the food I eat on a typical day …". Examples of items were "is low in calories" (weight control), "is cheap" (price), "is packaged in an environmentally friendly way" (ethical concern), and "cheers me up" (mood). Scores were on a scale where 1 = not at all important and 4 = very important. Scores on subscales are added and ranked to indicate relative importance of factors in shaping food choices.[20] The FCQ has been shown to have acceptable reliability (>0.70) and the internal consistency coefficients on its subscales range from 0.72 to 0.86.[20]

The 12-item Consideration of Future Consequences Scale (CFC)[20,21] was used to measure the extent to which people consider potential distant outcomes of their current behaviours (e.g., "I am willing to sacrifice my immediate happiness or well-being in order to achieve future outcomes."). Each statement is rated on a scale from 1 ("extremely uncharacteristic") to 5 ("extremely characteristic"). The scale scores range from 12 to 60, and a high CFC score indicates greater importance being placed on the future consequences of a behaviour, whereas a lower CFC score indicates greater importance being placed on the more immediate consequences of behaviour. Cronbach's α values for the CFC range from 0.80 to 0.86.[22,23] Eating in the Absence of Hunger (EAH) was measured using the EAH-C[24] scale. This scale is composed of 14-items that assess three dimensions related to stimuli that generate beginning or continuing to eat food in the absence of hunger. "Continuing EAH" is defined as continuing to eat immediately after being satiated at mealtime, and "beginning EAH" is defined as beginning to eat when not hungry several hours after being satiated.[24] Within these, the scale includes three motivators of eating in the absence of hunger: Negative affect (feeling sad or depressed, angry or frustrated, anxious or nervous); external eating (e.g., food looks, tastes or smells good and/or being in the presence of others who are eating); and fatigue/boredom. EAH-C was originally developed and validated for children and adolescents[24] but modified for college students and found to have high internal consistency across subscales (0.83–0.92).[25] In a subset of participants (n = 1162 [30.5%] WLM and 139 [26.8%] controls), the Diet History Questionnaire (DHQ-II) from the National Institutes of Health was used to measure self-reported calorie and macronutrient intake.[26] The DHQ-II was included as an exploratory and optional measure in the WWSR.[1]

Statistical analysis

Independent t-tests and a chi-squared analyses were used to compare socio-demographic characteristics of WLM vs. controls and completers vs. non-completers. Subsequent general linear models compared WLM and controls on scores of the FCQ measure (i.e., health, convenience, mood, sensory appeal, weight control, price, natural content, familiarity, and ethical concern), the CFC, and the EAH (beginning and continuing domains for external eating, negative affect, fatigue/boredom) and adjusted for a priori covariates of age, race (white vs. non-white), employment (employed vs. not), education (≥college education vs. < college), income (<$25,000, $25,000–75,000, ≥ 75,000/year), maximum lifetime weight, sex assigned at birth (male vs. female), and marital status (married vs. not).

Discriminant function analysis was used to determine the variables that most discriminated WLM from controls among the set of variables (subscale scores only) that were found to differ between the two groups in the initial general linear model analyses. The resulting standardised canonical coefficients represent the measure of association between the discriminant function (based on the linear combination of variables) and each predictor variable and indicate the relative importance each variable in distinguishing the two groups (similar to a beta weight in a multiple regression). Within each group (i.e., WLM and controls), BMI and dietary intake (in a subset) were examined in relation to the

FCQ, CFC, and EAH questionnaire scores, adjusting for the same covariates. To guard against type 1 error due to multiple analyses, statistical significance was set to $p < 0.01$ and small effect sizes ($\eta_p^2 < 0.03$) were considered as not significant. SPSS, version 25.0.0 (IBM Corp.) was used for all of the analyses.

RESULTS

Participants

Of the 8047 WLM and controls, 4325 completed the FCQ, which was situated in the second half of a lengthy questionnaire. Comparing participants who completed ($n = 4325$) vs. those who did not complete ($n = 3722$) the questionnaire, completers were older (53.6 [12.9] vs. 51.4 [12.8] years; $p = 0.0001$), more likely to be white (93.8% vs. 68.4%; $p = 0.0001$), less likely to be Hispanic (3.6% vs. 5.9%; $p = 0.0001$), and less likely to be employed (65.2% vs. 73.4%; $p = 0.0001$). Also, a greater proportion of controls than WLM completed the questionnaire (61.6% vs. 52.9%; $p = 0.0001$). Among participants, WLM and controls differed on several demographic factors (Table 1). Weight loss maintainers were more likely than controls to be older (54.5 vs. 46.7 years; $p = 0.0001$), female (91.8% vs. 78.6%; $p = 0.0001$), white (95.1% vs. 83.6%; $p = 0.0001$), married (74.7% vs. 51.1%; $p = 0.0001$), with an annual family income exceeding $75,000 (65.4% vs. 29.1%; $p = 0.0001$), and with at least a college education (89.5% vs. 84.6%; $p = 0.002$). Subsequent analyses statistically adjusted for these variables.

Motivators of food choices

In both groups, the top three factors rated as most important in food choices were health, convenience, and mood, and the lowest ranking factors were ethical concern, familiarity, and natural content (Table 2). Although health was the strongest reported motivation for food choice in both groups, WLM scored significantly higher than controls in the extent to which health influenced their food decisions (18.9 vs. 16.3; $\eta_p^2 = 0.052$; $p = 0.0001$) (Table 2). WLM also scored significantly higher than controls in reports of making food choices based on beliefs that the food aided in weight control (9.9 vs. 7.3; $\eta_p^2 = 0.159$; $p = 0.0001$). WLM reported lower scores than controls in making food decisions based on price (8.4 vs. 9.1; $\eta_p^2 = 0.10$; $p = 0.0001$). Both groups scored similarly on the extent to which convenience, mood, sensory appeal, natural content, familiarity, and ethical concerns shaped food choices. Examining future orientation, WLM reported greater consideration of future consequences (44.3 [95% confidence interval = 44.0–44.5] vs. 38.4 [37.8–39.1]; $\eta_p^2 = 0.060$; $p = 0.0001$). Also, WLM reported less eating in the absence of hunger during a meal in response to external cues (7.1 [7.0–7.2] vs. 7.5 [7.2–7.7]; $\eta_p^2 = 0.058$; $p = 0.0001$). WLM relative to controls reported consuming a smaller proportion of daily calories from fat (0.32 [0.32–0.33] vs. 0.38 [0.36–0.39]; $\eta_p^2 = 0.05$; $p = 0.001$) and a higher proportion of daily calories from protein (0.18 [0.18–0.19] vs. 0.16 [0.16–0.17]; $\eta_p^2 = 0.03$; $p = 0.0001$) (Table 2). No meaningful differences were observed in scores for eating in the absence of hunger at the initiation of a meal or in response to negative affect or fatigue/boredom (Table 2).

Multiple discriminant analysis

Multiple discriminant analysis was conducted to determine the factors that most strongly discriminated WLM from controls. Standardised canonical coefficients indicated that making food choices based on beliefs that the food aided in weight control (0.717) and less based on price (−0.330) and greater consideration of future consequences (0.262) contributed independently and most (overall $r = 0.593$; $p = 0.0001$) to discriminating the two groups (Table 3).

Relationships with BMI and dietary intake

Weight loss maintainers

Among WLM, higher scores on the weight subscale of the FCQ were related to greater weight loss from lifetime maximum weight ($b = 0.02$ [0.01–0.02]; $p = 0.0001$], lower current BMI ($b = -0.03$ [−0.04 to −0.02]; $p = 0.0001$]), lower daily percentage of calories from fat ($b = -4.01$ [−5.5 to −2.7); $p = 0.0001$], and higher daily percentage of calories from carbohydrate ($b = 2.6$ [1.4–3.7]; $p = 0.0001$). Similarly, higher scores on health subscale of the FCQ were related to greater weight loss from lifetime maximum weight ($b = 0.03$ [0.02–0.04]; $p = 0.0001$), lower current BMI ($b = -0.06$ [−0.08 to −0.03]; $p = 0.0001$], and higher daily percentage of calories from protein ($b = 9.7$ [4.3–15.3]; $p = 0.001$]. Higher scores on eating in the absence of hunger at the initiation of a meal were related to less weight loss from lifetime maximum weight ($b = -0.09$ [−0.12 to −0.06]; $p = 0.0001$], higher current BMI ($b = 0.22$ [0.15–0.30]; $p = 0.0001$], and greater daily calorie intake ($b = -0.002$ [0.001–0.0040; $p = 0.0001$]. Similar results were observed for eating in absence of hunger during a meal, which was related to less weight loss from lifetime maximum weight ($b = -0.09$ [−0.12 to −0.07]; $p = 0.0001$]), higher current BMI ($b = 0.22$, [0.15–0.29]; $p = 0.0001$], and greater daily calorie intake ($b = 0.002$ [0.001–0.003]; $p = 0.003$]. Higher scores on consideration of future consequences were related to more weight loss from lifetime maximum weight ($b = 0.07$ [0.05–0.09); $p = 0.0001$] and lower current BMI ($b = -0.18$ [−0.24 to −0.13]; $p = 0.0001$] but not dietary variables.

TABLE 1 Characteristics of weight loss maintainers following a commercial weight management program (WW International, Inc.) vs. weight stable individuals with obesity (controls)

	WLM		Controls		
	$n = 3806$[a]	SD	$n = 519$[a]	SD	p value
Age (years), mean	54.5	12.6	46.7	13.1	0.0001
Female (%)	91.8		78.6		0.0001
Currently in WW (%)	90.3		0		0.0001
Lifetime maximum weight, mean (kg)	105.8	23.0	121.4	27.9	0.0001
Weight at start of WW (kg), mean	101.7	21.3	Not applicable		Not applicable
Current weight (kg), mean	76.5	16.5	111.1	23.2	0.0001
Weight loss since WW start (kg), mean	25.2	12.7	Not applicable		Not applicable
Duration 9.1 kg loss from WW start weight (years), mean	3.2	3.2	Not applicable		Not applicable
Weight lost from maximum weight (kg), mean	29.3	15.4	10.3	14.3	0.0001
Current BMI (kg m^{-2}), mean	27.6	5.4	39.6	7.8	0.0001
BMI categories					0.0001
Obese (%)	22.3		100%		
Overweight (%)	44.3		0		
Normal weight (%)	33.4		0		
Underweight (%)	0.0		0		
Income (total in family per year)					0.0001
<$25,000 (%)	4.5		21.7		
$25,000–75,000 (%)	30.1		49.2		
≥$75,000 (%)	65.4		29.1		
Race/ethnicity					0.0001
White (%)	95.1		83.6		
Black (%)	2.3		11.9		0.0001
Hispanic (%)	3.3		6.0		0.003
Employed (%)	63.8		75.2		0.0001
College education or more (%)	89.5		84.6		0.002
Married (%)	74.7		51.1		0.0001

Abbreviation: WLM, weight loss maintainers.

[a]Some participants did not answer some of the socio-demographic questions. This reduced the total sample sizes/denominators as follows: Income (WLM, $n = 3392$; controls, $n = 509$), employment (WLM, $n = 3684$; controls, $n = 509$); education (WLM, $n = 3769$; controls, $n = 514$), and, marital status (WLM, $n = 3660$; controls, $n = 507$).

Controls

Among weight stable individuals with obesity, higher scores on the weight subscale of the FCQ ($b = -0.07$ [−0.11 to −0.03]; $p = 0.001$]) and on health subscale of the FCQ ($b = -0.13$ [−0.20 to −0.05]; $p = 0.002$] were related to lower current BMI. Also, higher scores on eating in the absence of hunger at the initiation of a meal were related to lower current BMI (0–0.25 [−0.04 to −0.06]; $p = 0.008$]. Scores on eating in absence of hunger during a meal and consideration of future consequences scales were not significantly ($p < 0.01$) related to BMI or dietary intake variables.

DISCUSSION

The present study is the first to comprehensively examine factors related to food choice among long-term WLM in a widely used commercial weight loss program. Compared with weight stable individuals with

obesity, WLM reported food decisions that were based more on beliefs that the food aided in weight control and based less on price. Moreover, WLM vs. weight stable individuals with obesity scored higher on future orientation, suggesting greater consideration of future consequences of their current behaviour. Future intervention research should determine the efficacy of strategies that make weight control

TABLE 2 Food choice motivations in weight loss maintainers and weight stable individuals with obesity (controls)

	WLM $n = 3327$[a]		Controls $n = 507$[a]		
	Mean	95% CI	Mean	95% CI	Group effect[b]
Food choice questionnaire					
Health	18.9	18.8, 19.0	16.3	16.0, 16.6	$\eta_p^2 = 0.052$; $p = 0.0001$**
Ranking	1		1		
Convenience	15.2	15.1, 15.3	15.4	15.1, 15.7	$\eta_p^2 = 0.001$; $p = 0.127$
Ranking	2		2		
Mood	13.4	13.2, 13.5	14.0	13.6, 14.4	$\eta_p^2 = 0.002$; $p = 0.002$
Ranking	3		3		
Sensory appeal	12.2	12.1, 12.3	12.0	11.8, 12.3	$\eta_p^2 = 0.0001$; $p = 0.204$
Ranking	4		4		
Weight control	9.9	9.8, 9.9	7.3	7.1, 7.5	$\eta_p^2 = 0.159$; $p = 0.0001$**
Ranking	5		6		
Price	8.4	8.3, 8.5	9.1	8.9, 9.3	$\eta_p^2 = 0.10$; $p = 0.0001$**
Ranking	6		5		
Natural content	8.2	8.1, 8.2	7.3	7.0, 7.5	$\eta_p^2 = 0.013$; $p = 0.0001$
Ranking	7		7		
Familiarity	6.8	6.7, 6.8	7.1	6.9, 7.2	$\eta_p^2 = 0.003$; $p = 0.002$
Ranking	8		8		
Ethical concern	5.8	5.7, 5.9	5.9	5.7, 6.1	$\eta_p^2 = 0.0001$; $p = 0.350$
Ranking	9		9		
Consideration of Future consequences, Total score (possible range from 12 to 60)	44.3	44.0, 44.5	38.4	37.8, 39.1	$\eta_p^2 = 0.060$; $p = 0.0001$**
Eating in absence of hunger	32.4	32.1, 32.7	32.8	31.8, 33.6	$\eta_p^2 = 0.0001$; $p = 0.523$
Beginning to eat while not hungry					
External eating (20 maximum)	7.5	7.4, 7.5	7.8	7.5, 8.0	$\eta_p^2 = 0.002$; $p = 0.018$
Negative affect (15 maximum)	10.9	10.8, 11.0	11.3	11.0, 11.6	$\eta_p^2 = 0.001$; $p = 0.026$
Fatigue/boredom (10 maximum)	3.8	3.7, 3.8	3.8	3.6, 3.9	$\eta_p^2 = 0.0001$ $p = 0.906$
Continuing to eat after satiated	33.8	33.5, 34.1	33.9	33.1, 34.8	$\eta_p^2 = 0.0001$; $p = 0.750$
External eating (15 maximum)	7.1	7.0, 7.2	7.4	7.2, 7.7	$\eta_p^2 = 0.058$; $p = 0.001$**
Negative affect (15 maximum)	8.3	8.2, 8.4	8.4	8.2, 8.7	$\eta_p^2 = 0.0001$; $p = 0.388$
Fatigue/boredom (15 maximum)	6.1	6.0, 6.2	5.9	5.7, 6.2	$\eta_p^2 = 0.0001$; $p = 0.296$
Dietary intake[c]					
Daily calorie intake	1499	1467, 1531	1618	1524, 1711	$\eta_p^2 = 0.005$; $p = 0.02$
Calories from fat (%)	0.32	0.32, 0.33	0.38	0.36, 0.39	$\eta_p^2 = 0.05$; $p = 0.001$**

(Continues)

TABLE 2 (Continued)

	WLM $n = 3327$[a]		Controls $n = 507$[a]		
	Mean	95% CI	Mean	95% CI	Group effect[b]
Calories from carbohydrate (%)	0.50	0.50, 0.51	0.46	0.44, 0.48	$\eta_p^2 = 0.02$; $p = 0.0001$
Calories from protein (%)	0.18	0.18, 0.19	0.16	0.16, 0.17	$\eta_p^2 = 0.03$; $p = 0.0001$**

Abbreviations: CI, confidence interval; WLM, weight loss maintainers; η_p^2, partial eta square.

[a]Some participants did not answer questions for income (WLM: $n = 414$; controls, $n = 10$), employment (WLM: $n = 122$; controls, $n = 10$), education (WLM: $n = 37$; controls, $n = 5$), and marital status (WLM: $n = 146$; controls, $n = 12$). Because these covariates were included in analyses, the total analytic sample for each group was reduced to $n = 3327$ for WLM and $n = 507$ for controls.

[b]Group effect based on general linear model adjusting for age, race, employment, education, income, maximum lifetime weight, biological sex, and marital status. Means are adjusted for these variables.

[c]Dietary intake was only measured in a subset. Sample sizes after excluding people with missing covariates were $n = 1007$ for WLM and $n = 132$ for controls.

**To guard against type 1 error due to multiple analyses, statistical significance was set to $p < 0.01$ and significance furthermore only interpreted for group differences that resulted in η_p^2 values ≥ 0.03.

TABLE 3 Multiple discriminant analysis to determine factors that most strongly discriminate weight loss maintainers from weight stable individuals with obesity

Variables entered into the model	Canonical discriminant function coefficients[a]
Consideration of future consequences	0.26
Food Choice Questionnaire – Health	−0.001
Food Choice Questionnaire – Weight	0.71
Food Choice Questionnaire – Price	−0.33
Eating in the absence of hunger – Continuing to eat in response to external cues	0.02
Overall canonical correlation	0.593; $p = 0.0001$*

[a]Adjusted for sex, income, age, race, education, lifetime maximum weight, marital status, and employment.

*$p < 0.01$.

goals more salient and cultivate future orientation during food decision-making processes.

Interestingly, WLM scored higher than weight stable individuals with obesity with respect to considering future consequences of current behaviours; also, higher scores on the consideration of future consequences scale were related to greater weight loss and lower BMI. The ability to delay gratification and think about future consequences has been prospectively linked with lower weight status,[27] and emergent research has found that future orientation may help individuals avoid eating in response to external cues and reduce impulsive eating.[28,29] Interventions that provoke vividly imagining the future or "episodic future thinking"[30] have been shown to reduce snacking[28] and ad libitum energy intake in the laboratory setting among individuals with obesity.[29] It is possible that an ability to engage in prospective thinking may be cultivated and used as an effective strategy for successful weight loss maintenance, although future clinical trial research is needed to address this hypothesis.

Making food choices based on beliefs that the food aided in weight control was a discriminating factor between WLM and weight stable individuals with obesity. Also, higher scores on making food decisions based on weight were related to lower BMI in both groups and to a greater initial weight loss and also a lower fat intake among WLM. The weight subscale of the FCQ is made up of ratings of importance of three items in determining food choices: "Is low in calories"; "helps me control my weight"; and "is low in fat." That WLM in WW scored higher than weight stable individuals with obesity on this subscale is consistent with the WW program goals, which include promoting healthy weight management and consumption of nutrient-dense foods. The WW points algorithm nudges towards foods that are lower in calories, sugar, and saturated fat; its zero point foods, including fruits and vegetable, can be eaten ad libitum.[31–34] Other studies have also found the weight subscale of the FCQ to be significantly correlated with dietary restraint[20] and consuming a diet with less red meat.[35] Future interventions should explore ways to elicit thoughts about the importance of weight control goals during the food decision-making process and determine impacts on food intake and weight management. Future research is also needed to examine whether higher FCQ-weight subscale scores are a defining characteristics among WLM in other contexts outside of WW.

Weight loss maintainers also made food choices less based on price compared to weight stable individuals with obesity. The WLM in the present study could have reported that cost was less influential of food choices because their income was, on average, higher than controls. However, statistical adjustments and stratified analyses within each income category (data not shown) suggested otherwise. In prior research of 83 low-income individuals with overweight/obesity vs. normal weight, those with overweight/obesity more commonly described being influenced by price when purchasing food compared to individuals with normal weight.[36] Other researchers have suggested that weight management approaches emphasising the high costs of foods such as

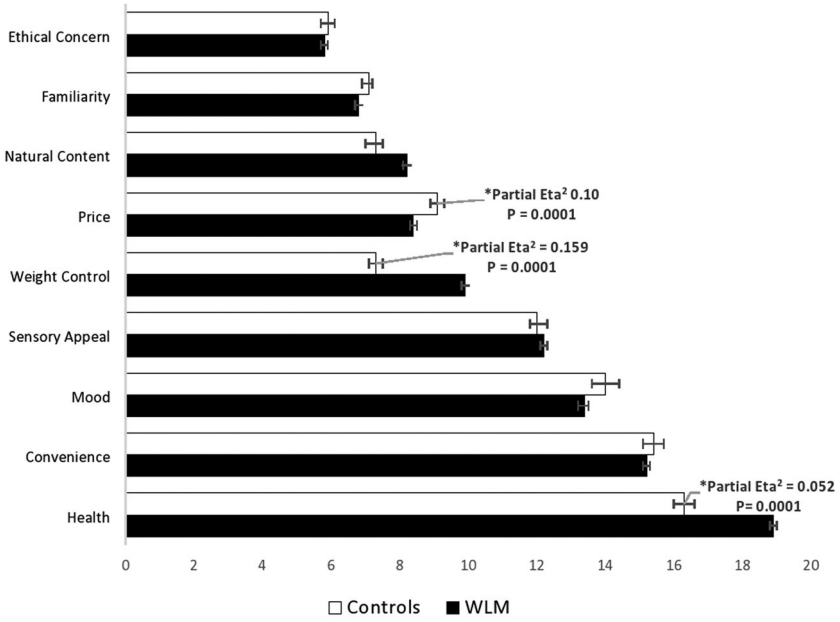

FIGURE 1 Food choice scores among weight loss maintainers (WLM) ($n = 3327$) and weight stable individuals with obesity ($n = 507$). Sample sizes remove participants without responses to socio-demographic covariates

fruits and vegetables may compound already existing barriers to consuming these foods and instead encourage the intake of less costly, energy-dense items.[37] Future prospective research is needed to understand the role of current income, food prices, and weight management priorities in shaping food decisions.

Eating in the absence of hunger has been related to weight gain[38] and to overeating.[39] In the present study, WLM reported less eating in the absence of hunger in response to external cues during a meal; also, less eating in the absence of hunger was related to a lower BMI. Research from the German Weight Control Registry[40] reported that WLM (vs. weight re-gainers) reported less propensity for eating in response to external cues. Nevertheless, in the present study, eating in the absence of hunger did not emerge as one of the strongest discriminator of WLM vs. weight stable individuals with obesity. Both WLM and weight stable individuals with obesity reported moderate levels of eating in the absence of hunger and scored similarly in eating in the absence of hunger as a result of negative affect, fatigue, and boredom.

The present study is the first to examine diverse factors related to food choices among WLM in a widely available commercial weight management program. The study included a comparison group of weight stable individuals with obesity and used validated measures. The study also has limitations. As a cross-sectional comparison, causality cannot be inferred. The study's measures were based on self-report and assumed that people were aware of the factors that shaped food choices. FCQ subscales were related with food intake was only measured in approximately 30% of participants, and these results should be interpreted with caution. There were several other, unmeasured factors, including the obesogenic environment, social factors, and biological factors that all contribute to food choice.[41,42] The study adjusted for sociod-emographic differences, and the results of the regression analyses within both groups suggested sporadic relationships between socio-demographic variables and the subscales of interest. Nevertheless, these and other unmeasured socio-demographic characteristics could account for the observed differences between groups. Participants were self-selected and results may not be generalisable to other populations.

CONCLUSIONS

Individuals in WW who were successful at long-term weight loss maintenance differed from weight stable individuals with obesity in that they made food decisions more based on weight control goals and less based on price. Also, WLM were more likely to consider future consequences of their current behaviours. Future intervention research is needed to determine the effects of strategies that make weight management goals more salient during food decision making processes and that cultivate future orientation as a means to improve long-term weight loss maintenance (Figure 1).

ACKNOWLEDGEMENTS

This research was supported by a grant from WW International, Inc. and student fellowship support from The William and Linda Frost Fund at California Polytechnic State University.

CONFLICT OF INTERESTS

Suzanne Phelan reports receiving a research grant from WW International, Inc. Rethorst was previously an employee and shareholder of WW. Foster is an employee and shareholder of WW.

ETHICAL STATEMENT

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the California Polytechnic State University, San Luis Obispo Institutional Review Board. Written informed consent was obtained from all participants via REDCap.

AUTHOR CONTRIBUTIONS

Study concept and design: Suzanne Phelan, Gary D. Foster, and Chad D. Rethorst. Analysis and interpretation of data: Suzanne Phelan, Jacob Young, and James Roake. Data collection and management: Noemi Alarcon. Drafting of the manuscript: Jacob Young, James Roake, and Suzanne Phelan. Critical revision of the manuscript for important intellectual content: Suzanne Phelan, Gary D. Foster, and Chad D. Rethorst. Administrative, technical or material support: Noemi Alarcon. Study supervision: Suzanne Phelan. Suzanne Phelan had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

TRANSPARENCY DECLARATION

The lead author affirms that this manuscript is an honest, accurate and transparent account of the study being reported. The reporting of this work is compliant with STROBE guidelines. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned have been explained.

ORCID

Suzanne Phelan http://orcid.org/0000-0003-2260-0499

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1111/jhn.12977

REFERENCES

1. Pascual RW, Phelan S, La Frano MR, Pilolla KD, Griffiths Z, Foster GD. Diet quality and micronutrient intake among long-term weight loss maintainers. Nutrients. 2019;11:11.
2. Gorin AA, Phelan S, Wing RR, Hill JO. Promoting long-term weight control: does dieting consistency matter? Int J Obes Relat Metab Disord. 2004;28:278–81.
3. Klem ML, Wing RR, McGuire MT, Seagle HM, Hill JO. A descriptive study of individuals successful at long-term maintenance of substantial weight loss. Am J Clin Nutr. 1997;66:239–46.
4. Chen PJ, Antonelli M. Conceptual models of food choice: influential factors related to foods, individual differences, and society. Foods. 2020;9:1898.
5. Rankin A, Bunting BP, Poínhos R, van derLans IA, Fischer AR, Kuznesof S, et al. Food choice motives, attitude towards and intention to adopt personalised nutrition. Public Health Nutr. 2018;21:2606–16.
6. Pula K, Parks CD, Ross CF. Regulatory focus and food choice motives. Prevention orientation associated with mood, convenience, and familiarity. Appetite. 2014;78:15–22.
7. Steenkamp J-BEM. Dynamics in consumer behavior with respect to agricultural and food products. In: Wierenga B, van Tilburg A, Grunert K, Steenkamp J-BEM, Wedel M, editors. Agricultural marketing and consumer behavior in a changing world. New York: Springer; 1997. p. 143–88.
8. Wu WH, Cheng W, Chiou WB. Episodic future thinking about the ideal self induces lower discounting, leading to a decreased tendency toward cheating. Front Psychol. 2017;8:287.
9. Koenders PG, van Strien T. Emotional eating, rather than lifestyle behavior, drives weight gain in a prospective study in 1562 employees. J Occup Environ Med. 2011;53:1287–93.
10. Ganley RM. Emotion and eating in obesity: a review of the literature. Int J Eat Disord. 1989;8:343–61.
11. Montmayeur JP, le Coutre J. Fat detection: Taste, texture, and post ingestive effects. Boca Raton, FL: CRC Press/Taylor & Francis; 2010.
12. Dietary Guidelines Advisory Committee. Scientific report of the 2020 Dietary Guidelines Advisory Committee: advisory report to the Secretary of Agriculture and the Secretary of Health and Human Services. Washington, DC: U.S. Department of Agriculture, Agricultural Research Service; 2020.
13. Phelan S, Halfman T, Pinto AM, Foster GD. Behavioral and psychological strategies of long-term weight loss maintainers in a widely available weight management program. Obesity (Silver Spring). 2020;28:421–8.
14. Roake J, Phelan S, Alarcon N, Keadle SK, Rethorst CD, Foster GD. Sitting time, type, and context among long-term weight-loss maintainers. Obesity (Silver Spring). 2021;29:1067–73.
15. Jensen MD, Ryan DH, Apovian CM, Ard JD, Comuzzie AG, Donato KA, et al. 2013 AHA/ACC/TOS guideline for the management of overweight and obesity in adults: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society. J Am Coll Cardiol. 2014;63:2985–3023.
16. Look Ahead Research Group, Pi-Sunyer X, Blackburn G, et al. Reduction in weight and cardiovascular disease risk factors in individuals with type 2 diabetes: one-year results of the look AHEAD trial. Diabetes Care. 2007;30:1374–83.
17. Wing RR, Phelan S. Long-term weight loss maintenance. Am J Clin Nutr. 2005;82:222S–5S.
18. McGuire MT, Wing RR, Klem ML, Hill JO. Behavioral strategies of individuals who have maintained long-term weight losses. Obes Res. 1999;7:334–41.
19. McGuire MT, Wing RR, Klem ML, Lang W, Hill JO. What predicts weight regain in a group of successful weight losers? J Consult Clin Psychol. 1999;67:177–85.
20. Steptoe A, Pollard TM, Wardle J. Development of a measure of the motives underlying the selection of food: the food choice questionnaire. Appetite. 1995;25:267–84.
21. Strathman A, Gleicher F, Boninger DS, Edwards CS. The consideration of future consequences – weighing immediate and distant outcomes of behavior. J Pers Soc Psychol. 1994;66:742–52.
22. Joireman J, Strathman A, Balliet D. Considering future consequences: an integrative model. In: Sanna LJ, Chang EC, editors. Judgments over time: the interplay of thoughts, feelings, and behaviors. Oxford: Oxford University; 2006. p. 82–99.
23. Joireman J, Shaffer MJ, Balliet D, Strathman A. Promotion orientation explains why future-oriented people exercise and eat healthy: evidence from the two-factor consideration of future consequences-14 scale. Pers Soc Psychol Bull. 2012;38:1272–87.
24. Tanofsky-Kraff M, Ranzenhofer LM, Yanovski SZ, Schvey NA, Faith M, Gustafson J, et al. Psychometric properties of a new questionnaire to assess eating in the absence of hunger in children and adolescents. Appetite. 2008;51:148–55.
25. Pérez-Morales E, Jiménez-Cruz A, Alcántara-Jurado L, Armendáriz-Anguiano A, Bacardí-Gascón M. Association of obesity and eating in the absence of hunger among college students in a Mexican-USA border city. J Community Health. 2014;39:432–6.
26. National Institutes of Health Applied Research Program. Diet History Questionnaire, Version 3.0. National Cancer Institute; 2015.

27. Davis C, Patte K, Curtis C, Reid C. Immediate pleasures and future consequences. A neuropsychological study of binge eating and obesity. Appetite. 2010;54:208–13.
28. Dassen FCM, Jansen A, Nederkoorn C, Houben K. Focus on the future: Episodic future thinking reduces discount rate and snacking. Appetite. 2016;96:327–32.
29. Daniel TO, Stanton CM, Epstein LH. The future is now: reducing impulsivity and energy intake using episodic future thinking. Psychol Sci. 2013;24:2339–42.
30. Atance CM, O'Neill DK. Episodic future thinking. Trends Cogn Sci. 2001;5:533–9.
31. Jolly K, Lewis A, Beach J, Denley J, Adab P, Deeks JJ, et al. Comparison of range of commercial or primary care led weight reduction programmes with minimal intervention control for weight loss in obesity: lighten Up randomised controlled trial. BMJ. 2011;343:d6500.
32. Heshka S, Anderson JW, Atkinson RL, Greenway FL, Hill JO, Phinney SD, et al. Weight loss with self-help compared with a structured commercial program: a randomized trial. JAMA. 2003;289:1792–8.
33. Gudzune KA, Doshi RS, Mehta AK, Chaudhry ZW, Jacobs DK, Vakil RM, et al. Efficacy of commercial weight-loss programs: an updated systematic review. Ann Intern Med. 2015;162:501–12.
34. Ahern AL, Wheeler GM, Aveyard P, Boyland EJ, Halford J, Mander AP, et al. Extended and standard duration weight-loss programme referrals for adults in primary care (WRAP): a randomised controlled trial. Lancet. 2017;389:2214–25.
35. Pollard TM, Steptoe A, Wardle J. Motives underlying healthy eating: using the Food Choice Questionnaire to explain variation in dietary intake. J Biosoc Sci. 1998;30:165–79.
36. Dressler H, Smith C. Food choice, eating behavior, and food liking differs between lean/normal and overweight/obese, low-income women. Appetite. 2013;65:145–52.
37. Drewnowski A, Darmon N. Food choices and diet costs: an economic analysis. J Nutr. 2005;135:900–4.
38. Feig EH, Piers AD, Kral TVE, Lowe MR. Eating in the absence of hunger is related to loss-of-control eating, hedonic hunger, and short-term weight gain in normal-weight women. Appetite. 2018;123:317–24.
39. Goldschmidt AB, Crosby RD, Cao L, Pearson CM, Utzinger LM, Pacanowski CR, et al. Contextual factors associated with eating in the absence of hunger among adults with obesity. Eat Behav. 2017;26:33–9.
40. Neumann M, Holzapfel C, Müller A, Hilbert A, Crosby RD, de Zwaan M. Features and trajectories of eating behavior in weight-loss maintenance: results from the German Weight Control Registry. Obesity (Silver Spring). 2018;26:1501–8.
41. Leng G, Adan RAH, Belot M, Brunstrom JM, de Graaf K, Dickson SL, et al. The determinants of food choice. Proc Nutr Soc. 2017;76:316–27.
42. Qualls-Creekmore E, Marlatt KL, Aarts E, Bruce-Keller A, Church TS, Clément K, et al. What should I eat and why? The environmental, genetic, and behavioral determinants of food choice: summary from a Pennington scientific symposium. Obesity (Silver Spring). 2020;28:1386–96.

AUTHOR BIOGRAPHIES

Jacob Young, BS, received his an undergraduate degree in Kinesiology at California Polytechnic State University in the Department of Kinesiology & Public Health and was a Student Research Associate of the Center for Health Research, San Luis Obispo, CA, USA. His research interests include accelerometer-based measurement of physical activity and determinants of food choice.

Suzanne Phelan, PhD, is Professor in the Department of Kinesiology & Public Health and Director of the Center for Health Research at California Polytechnic State University, San Luis Obispo, CA, USA. Her research interests include weight loss maintenance, behavioural treatment of obesity, and women's health.

Noemi Alarcon, BS, is Project Coordinator in the Center for Health Research at California Polytechnic State University, San Luis Obispo, CA, USA. Her research interests include global health, women's health, and data and clinical trial management.

James Roake is an undergraduate student in Public Health at California Polytechnic State University in the Department of Kinesiology & Public Health and a Student Research Associate in the Center for Health Research, San Luis Obispo, CA, USA. His research interests include physiology and management of obesity and global health advocacy.

Chad D. Rethorst, PhD, is Associate Professor in Texas A&M Agrilife Research, Dallas, TX, USA and former Director of Clinical Research at WW International, Inc, New York, NY, USA. His research interests include weight management and physical activity to improve mental health.

Gary D. Foster, PhD, is Chief Scientific Officer at WW International, Inc., New York, NY, USA and Adjunct Professor of Psychology in Psychiatry at Perelman School of Medicine, University of Pennsylvania, Center for Weight and Eating Disorders, Philadelphia, PA, USA. His research interests include scalable, evidence-based approaches to wellness for adults and children in community settings.

How to cite this article: Young J, Phelan S, Alarcon N, Roake J, Rethorst CD, Foster GD. Factors associated with food choice among long-term weight loss maintainers. J Hum Nutr Diet. 2022;35:924–933. https://doi.org/10.1111/jhn.12977

Received: 27 August 2021 | Accepted: 11 November 2021

DOI: 10.1111/jhn.12972

JHND Journal of Human Nutrition and Dietetics | BDA The Association of UK Dietitians

Evaluating nutrition education interventions for medical students: A rapid review

Priya Patel[1] | **Shireen Kassam**[2,3]

[1]College of Medicine and Health, St Luke's Campus, University of Exeter, Exeter, UK

[2]Department of Haematology, Kings College Hospital, Denmark Hill, London

[3]Faculty of Health and Wellbeing, University of Winchester, Winchester, Hampshire

Correspondence

Priya Patel, College of Medicine and Health, St Luke's Campus, University of Exeter, Heavitree Road, Exeter EX1 2LU, UK.
Email: Priyapatel97@hotmail.co.uk

Funding information

None

Abstract

Background: Unhealthy diets account for 20% of all deaths globally. Most medical schools do not sufficiently teach their students the clinical application of nutrition science. Evaluating the efficacy of nutrition education interventions is therefore important for their widespread implementation.

Methods: A rapid review of the literature published between 2015 and 2020 was conducted to identify nutrition education interventions delivered to undergraduate medical students. The modified Kirkpatrick hierarchy score was used to evaluate the outcome measures. Study characteristics and outcomes were charted and discussed using narrative synthesis. Included studies were appraised using the MERSQI criteria.

Results: Fifteen nutrition education interventions met the inclusion criteria. Twelve were from the USA and most were optional rather than compulsory. Interventions involved a mixture of methods including cooking sessions, lectures, and student-led programs. The content covered was variable and the median duration was 11 h (range 90 min to 75 h). The modified Kirkpatrick scores varied and the median MERSQI score was 12.8/18. No studies reported the use of national or standardised guidance to inform the learning objectives of the interventions.

Conclusions: The interventions reviewed are heterogenous in their nature and outcomes. This review highlights the advantages of utilising interprofessional learning, focusing on student's personal health behaviours and harnessing novel teaching methods such as hands-on cooking. Using national guidance to develop learning outcomes will help to standardise the content taught. Future studies may aim to use validated assessment tools and investigate the long-term impacts on delivery of care and patient outcomes.

KEYWORDS

culinary medicine, diet, medical education, nutrition education

Key points

- Increased nutrition training in medical education is needed.
- A variety of teaching approaches were identified, including novel methods such as culinary medicine and service learning.
- Future research is needed to further evaluate nutrition education interventions, including patient health outcomes.
- Development and utilisation of national guidance is needed to standardise content.

[Correction added on 24 December 2021, after first online publication: Peer review history statement has been added.]

INTRODUCTION

Globally, unhealthy diets contribute to more deaths than any other risk factor and approximately 20% of all death scan be attributed to a suboptimal diet.[1] Nutrition therefore plays a crucial role in the prevention and treatment of non-communicable diseases,[2–4] which account for 89% and 88% of all deaths in the UK and USA, respectively.[5,6] In line with this, the UK's General Medical Council states that graduates should be able to discuss the role and impact of nutrition on health.[7] In the USA, the Association of American Medical Colleges endorsed a bill in the US congress in 2019 to enhance nutrition education within medical school curricula, although this bill was not endorsed into legislation.[8,9] Nutrition is also of topical importance considering the significant role that diet plays in the development of many of the risk factors associated with severe COVID-19.[10,11]

Despite acknowledgement of the importance of nutrition, there is still a significant under-representation of nutrition education in medical school curricula,[12] which also appears to extend to postgraduate medical training.[13] The most recent systematic review on this topic found that, regardless of country, setting or year of medical education, medical students report inadequate knowledge, skills and confidence to support patients in making sustainable dietary changes.[14] Crowley et al.[14] also found that, when initiatives are incorporated into curricula, their impact is modest as a result of the heterogeneity of approaches and lack of robust tools for evaluation, thus leading to recommendations to establish competencies as a means of benchmarking nutrition knowledge and skill. Identifying effective strategies to teach medical students about nutrition is therefore essential. Teaching methods recommended by a systematic review evaluating nutrition education interventions in health professionals included interprofessional learning (IPL) and interventions that place an emphasis on learners' personal health behaviours.[15]

The present study aimed to evaluate nutrition education interventions delivered to medical students published between 2015 and 2020 to assess recent efforts in this field subsequent to publication of the prior systematic review.[15] Here, we define nutrition education as any educational experience related to the role of nutrition in health within the context of undergraduate medical education.

METHODS

Search strategy

A rapid review of the literature was conducted using Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. A search (by PP) was conducted in Medline (via OvidSp), Scopus and ERIC (via EBSCOhost) (22/10/20) for relevant papers published from October 2015 to October 2020. This timeframe was chosen as an extension of a systematic review of nutrition education interventions conducted 5 years ago.[15] The search terms used included (Medical student* or Medical school* or Medical undergraduate*) AND (Nutrition* education or Nutrition* intervention* or Nutrition* curricul* or Nutrition* training). The search terms used for each database are detailed in the Supporting information (Table S1). A forwards-citation search of the aforementioned systematic review was conducted[15] and a backwards-citation search was conducted on a recent systematic review of nutrition in medical education.[14]

Study selection

The aim of the selection process was to identify any English-language empirical studies that quantitatively evaluated nutrition education interventions delivered to medical students. The inclusion and exclusion criteria used to determine eligibility are shown in Table 1. All citations were managed using EndNote Online (https://endnote.com). Duplicates were removed by hand.

TABLE 1 Inclusion/exclusion criteria

Inclusion	Exclusion
Empirical study presenting quantitative data	Not published in English
Published within the past 5 years (October 2015–2020)	Unable to isolate the outcomes of medical students from cohort
Intervention delivered to undergraduate medical students	Unable to isolate the outcomes of nutrition education intervention from a general lifestyle medicine intervention
	Delivers non-generalisable nutrition education of specific patient groups
	Unable to view full text
	Assessment alone was not considered as a nutrition education intervention

Data extraction

Key information was extracted (by PP) from the included studies, identifying study design, intervention methods and modified Kirkpatrick's hierarchy score.[16] Evaluating the effectiveness of nutrition education interventions is key in recognising their impact and shaping the development of future interventions. The Kirkpatrick model is a recognised method for 'classifying the effectiveness of an intervention according to different educational outcomes'.[16] The data extraction and descriptive statistics used were adapted from the previous systematic review on nutrition education interventions.[15]

Quality appraisal

The Medical Education Research Study Quality Instrument (MERSQI) was used to appraise the included studies.[17] There was no MERSQI score cut-off for inclusion within the review. The total score was calculated as a percentage of points adjusting for non-applicable responses, giving a maximum score of 18.

RESULTS

In total, 178 papers were identified through the initial database search and 17 from citation chasing (Figure 1). After removing 69 duplicates, the remaining 126 papers were screened for eligibility based on the inclusion and exclusion criteria (Table 1) by assessing the title and/or abstract. Of these, 101 papers did not meet the inclusion criteria and were excluded. The full text of the remaining 25 papers was reviewed (by PP), of which 10 did not meet the inclusion criteria and were removed. The remaining 15 papers are evaluated in this review. A summary of the intervention descriptions,

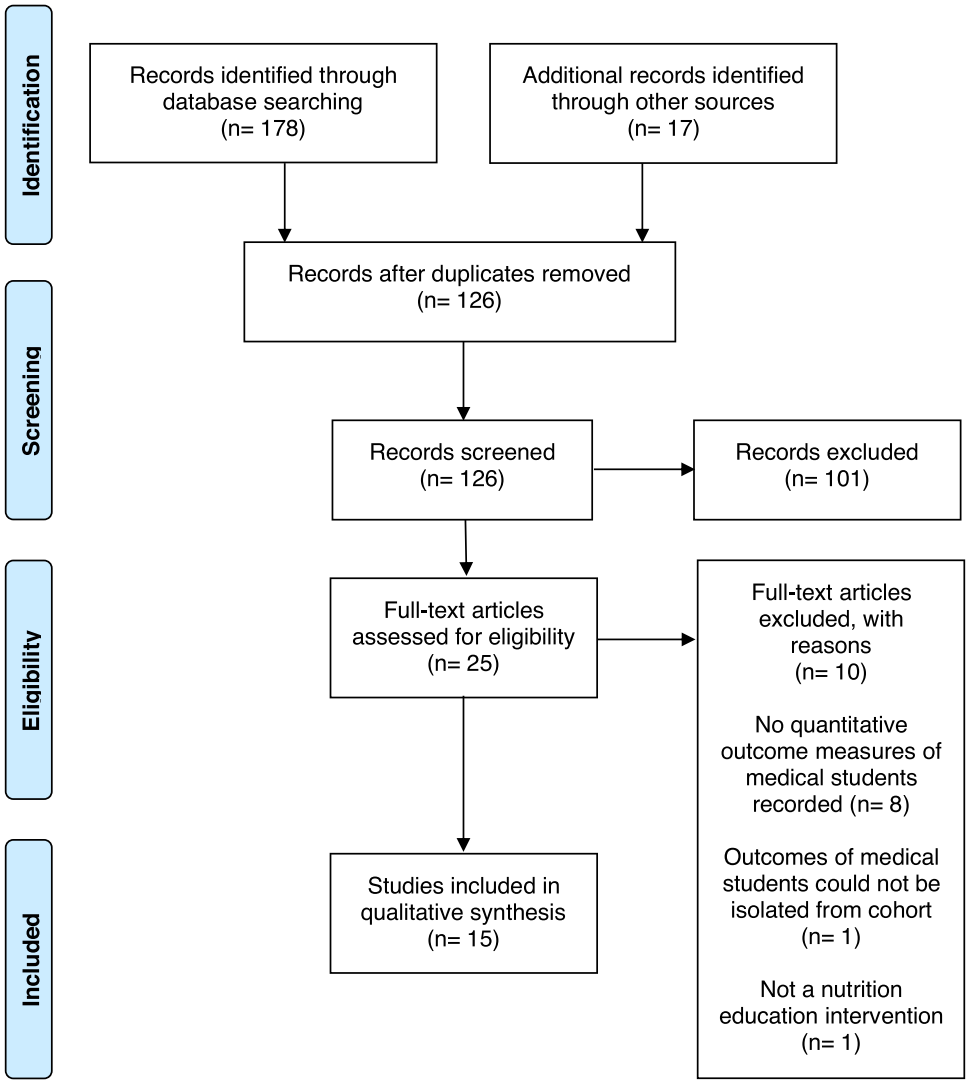

FIGURE 1 Preferred Reporting Items for Systematic reviews and Meta-Analyses diagram

reported findings and MERSQI scores of the included papers is provided in Table 2.

Most ($n = 12$) of the studies were conducted in the USA, with the remaining from the UK,[20] the Netherlands[22] and Portugal.[26] Four of the interventions were required,[21,24,26,28] whereas the rest were elective (optional). Five of these interventions were described as pilot studies.[18,20,29,31,32] The median number of participants was 51, ranging from 15[20] to 3248.[25] Interventions either allowed students of all year groups to participate[22,25,32] or were specific to year[19,20,24,27,28,31] and clinical groups.[18,21,23,26,29,30] The median duration of all the interventions was 11 h, ranging from 90 min[19] to 75 h.[26] However, three studies did not report the length of the student-led component of the course.[29–31]

Content areas and teaching methods

Nine of the interventions addressed specific patient populations. For example, Coppoolse et al.[22] implemented a 10-week elective course involving 25 experts hosting lectures covering a different topic related to nutrition and disease over 25 h. Lectures included 'nutrition and diabetes', 'nutrition and cancer' and 'nutrition and cardiovascular disease'. Nine interventions included basic nutrition science; for example, Mota et al.[26] delivered a nutrition and metabolism required curricula unit for first year students. Contents included metabolic pathways, micro- and macronutrients, and regulation of food intake. Culinary medicine was utilised in seven studies.[23–25,27,29,31,32] Dietary counselling was covered in six of the identified interventions.[19–21,24,28,29] Most of the studies incorporated a combination of content areas. For example, Jacob et al.[24] delivered a single day culinary laboratory where students had to identify certain micro- and macronutrients that would benefit a patient case study and consider the metabolic pathways and food sources for these nutrients before cooking a tailored recipe. No studies reported the use of national or standardised guidance to inform the learning objectives of the interventions.

A range of teaching methods were used. Five studies incorporated a student-led component where medical students taught each other,[18] school children[18,25,26] or families[30] about nutrition. One study used a student-led evidence-based nutrition lecture series involving a total of five peer taught lectures.[18] A survey found that 93% ($n = 14$) of students agreed with the statement: 'I like the peer teaching aspect of this lecture series and think it is an effective way to learn'. Ronecker et al.[30] developed a didactic curriculum with a 6-8-week student-led family coaching program. This involved a 7-h coaching and nutrition training course followed by weekly meetings with at-risk children and their families. Similarly, Ring et al.[29] involved both a teaching and service component, where medical students taught school children about healthy eating after a nutrition training course involving a combination of didactics and culinary medicine. Students reported increased confidence in nutrition and obesity counselling after the course ($p < 0.001$).

Four interventions were explicit in harnessing IPL as part of the teaching methods.[19,21,24,27] One study developed an interprofessional nutrition workshop that was jointly facilitated by registered dietitians who 'provided experience and critical content' for the session.[21] Additionally, student dietitians participated in the planning and facilitation of the experiential culinary laboratory of Jacob et al.[24] The results of a questionnaire used to evaluate medical student's attitudes towards the culinary laboratory found that the participants rated the knowledge of the student dietitians highly and above their own ($p < 0.001$).[24] Other teaching methods used include cooking sessions,[23–25,27,29,31,32] lectures[18–20,22,27,29,30,32] and case-based discussions.[24,26–28,31]

Instructors varied and with some involving a combination of professions, including dietitians,[19–22,24,26,27,30,31] physicians,[20,21,27,31,32] chefs,[27,29,32] and psychologists.[20,22] Pang et al.[27] delivered a 6-week hands-on culinary and nutrition course, with each session delivered jointly by a physician, dietitian and chef. The multidisciplinary approach allowed the course to cover content including disease pathophysiology, dietary management and meal preparation on a limited budget as a result of the wide range of faculty expertise.

Evaluation design and learning outcomes

Two studies used a single group post-test only design.[18,24] The remaining studies used a single group pre- and post-test design, with three of these also including a non-randomised control group.[21,22,25] Learning outcomes were measured using the Best Evidence in Medical Education (BEME) adapted Kirkpatrick's hierarchy.[16] Learning outcomes achieved include changes in behaviour (Level 3),[21,23,25,26] knowledge (Level 2b),[20,22,27,30] attitudes (Level 2a)[28,29,31,32] and satisfaction (Level 1).[22,24] No studies reported an impact on delivery of care (level 4a) or patient outcomes (Level 4b).

Four studies demonstrated significant improvements in the learner's self-reported health behaviours,[23,25,26,29] three of which involved a culinary medicine component. For example, Monlezun et al.[25] evaluated a multisite cohort trial on hands-on cooking and nutrition education of 3248 medical students from over 45 institutions in the USA. This study found significantly higher self-reported adherence to a Mediterranean diet in the culinary medicine program cohort compared with the traditional curricula cohort (odds ratio = 1.40, 95% confidence interval = 1.07–1.84, $p = 0.015$). Additionally, Mota et al.[26] found improved self-reported health behaviours, including avoidance of foods high in fat and/or sugar ($p < 0.001$), after a classroom-based nutrition and metabolism compulsory curricula unit. One study

TABLE 2 Summarising of the 15 included studies

Study Author (year) Country	Intervention description	Compulsory or elective	Study design and participants	Type of instructor	Setting	Method of intervention	Duration	Content areas covered	Improved outcomes (Kirkpatrick hierarchy[a])	MERSQI Score/18
Baute et al. (2017) USA[18]	Pilot intervention of a student-led evidence-based lecture series	Elective	Single group post-test only. Clinical medical students ($n = 65$)	Medical student	Classroom	Lecture Student-led peer-assisted learning	5 h	Not reported	Satisfaction[1]	7.2
Berz et al. (2020) USA[19]	Interprofessional nutrition session	Elective	Single group pre-test and post-test Fourth year medical students ($n = 42$)	Dietitian Physician	Classroom	Lecture Interprofessional Workshop	90-min	Basic science nutrition Dietary counselling Diet history taking	Attitudes Knowledge Clinical skills (2b)	12.6
Broad et al. (2018) UK[20]	Pilot intervention of a 6-week nutrition course with a student-led school-based teaching component	Elective	Single group pre-test and post-test Final-year medical students ($n = 15$)	Dietitian Manager Pharmacist Physician Psychologist	Classroom School	Lecture Student-led service learning[b] Workshop	11 h	MDietary counselling Specific patient population	Knowledge (2b)	12
Cavuoto Petrizzo (2020) USA[21]	Interprofessional nutrition workshop integrated within the pre-clinical curricula	Required	Single group pre-test and post-test Pre-clinical medical students ($n = 63$)	Dietitian Physician	Classroom	Interprofessional Workshop	2 h	Basic nutrition science Dietary counselling Diet history taking	Satisfaction Attitudes (2a)	12.6
			Nonrandomized, 2 group Pre-clinical medical students ($n = 197$)						Behaviour (3)	15
Coppoolse (2020) The Nether-lands[22]	10-week lifestyle and nutrition course	Elective	Single group pre-test and post-test Non-randomized, 2 group Medical students (all years) ($n = 118$)	Dietitian Nutritionist Psychologist	Classroom	Lecture	25 h	Specific patient population	Knowledge (2b)	13.2
Flynn et al. (2019) USA[23]	4-week plant-based cooking program	Elective	Single group pre-test and post-test First and second year medical students ($n = 43$)	Not reported	Kitchen	Cooking session	2 h	Dietary patterns Learner's health behaviour	Knowledge Learner's health behaviour (3)	13.2

(Continues)

TABLE 2 (Continued)

Study Author (year) Country	Intervention description	Compulsory or elective	Study design and participants	Type of instructor	Setting	Method of intervention	Duration	Content areas covered	Improved outcomes (Kirkpatrick hierarchy[a])	MERSQI Score/18
Jacob et al. (2016) USA[24]	Pilot intervention of a 1-day culinary cooking laboratory for first-year medical students	Compulsory	Single group post-test only First year medical students ($n = 90$)	Student dietitian	Kitchen	Case-based discussion Cooking session Interprofessional	6 h	Basic nutrition science Culinary medicine Dietary counselling	Satisfaction (1)	9.6
Monlezun et al. (2018) USA[25]	Multisite cohort study of students from 20 medical schools over 5 years	Elective	Single group pre-test and post-test Non-randomised, 2 group Medical students (all years) ($n = 3248$)	Not reported	Classroom Kitchen Online	Cooking session Problem based learning	28 h	Basic nutrition science Culinary medicine Specific patient population	Knowledge Learner's health behaviour (3)	13.8
Mota et al. (2020) Portugal[26]	Nutrition and metabolism curricula unit for first year medical students	Compulsory	Single group pre-test and post-test Pre-clinical medical students ($n = 310$)	Dietitian	Classroom	Case-based discussion Problem based learning	75 h	Basic nutrition science Population health Specific patient populations	Attitudes Knowledge Learner's health behaviour (3)	13.2
Pang et al. (2019) USA[27]	6-week culinary medicine course for second year medical students	Elective	Single group pre-test and post-test Second year medical students ($n = 15$)	Chef Dietitian Physician	Kitchen	Case-based discussion Lecture Cooking session Interprofessional	15 h	Culinary medicine Specific patient populations	Attitudes Knowledge (2b)	13.8
Ramsetty et al. (2020) USA[28]	Pilot intervention of case-based nutrition education session via video conferencing	Compulsory	Single group pre-test and post-test Third year medical students ($n = 58$)	Not reported	Online	Case-based discussion	2 h	Dietary counselling Specific patient populations	Attitudes (2a)	8.4

TABLE 2 (Continued)

Study Author (year) Country	Intervention description	Compulsory or elective	Study design and participants	Type of instructor	Setting	Method of intervention	Duration	Content areas covered	Improved outcomes (Kirkpatrick hierarchy[a])	MERSQI Score/18
Ring et al. (2018) USA[29]	Pilot intervention combining didactics, culinary sessions with a student-led school-based teaching component	Elective	Single group pre-test and post-test First and second year medical students ($n = 21$)	Chef	Classroom Kitchen School	Lecture Cooking session Student-led service learning	15 h plus student-led component (not reported)	Basic nutrition science Culinary medicine Dietary counselling Population health Specific patient populations	Attitudes Learner's health behaviour (3)	11.4
Ronecker et al. USA (2019)[30]	Didactic curriculum with a 6-8-week student-led family coaching program	Elective	Single group pre-test and post-test First and second year medical students ($n = 25$)	Dietitian Physician	Classroom Community[c]	Lecture Student-led service learning	7 h plus student-led component (not reported)	Specific patient populations Population health	Attitudes Knowledge (2b)	12.6
Rothman et al. (2020) USA[31]	Pilot intervention culinary sessions with disease specific case-based discussions with a student-led school-based teaching component	Elective	Single group pre-test and post-test Fourth year medical students ($n = 30$)	Dietitian Physician	Classroom Kitchen School	Cooking session Case-based discussion Patient experience Student-led service learning	16 h plus student-led component (not reported	Basic nutrition science Culinary medicine Specific patient populations	Attitudes (2a)	8.4
Shafto et al. (2016) USA[32]	Pilot intervention combining didactic and culinary sessions	Elective	Single group pre-test and post-test Medical students (all years) ($n = 17$)	Chef Physician	Kitchen	Cooking session Lecture	18 h	Basic nutrition science Dietary patterns Culinary medicine	Attitudes (2a)	10.2

[a]Modified Kirkpatrick levels based on Best Evidence in Medical Education: (1) learners' views on the intervention, (2a) learners' attitudes toward the intervention, (2b) learners' improved knowledge or skills, (3) learners' behaviour change, (4a) delivery of care or (4b) patient outcomes.

[b]Service-learning: Students teaching members of the community.

[c]Community: Outside of the institution or school setting.

assessed for behaviour change by comparing the student's Objective Structured Clinical Exam (OSCE) scores with a historical control group.[21]

Study quality

The median MERSQI score was12.6/18, ranging from 8.4[18] to 15.[21] All studies used surveys sent to the participants as one way to evaluate the intervention. Four studies either used a previously validated survey[25,26] or took steps to validate their own.[21,22] The validity of instrument domain of the MERSQI was excluded for most studies because the data collected were not considered applicable except for one study, which included an objective skills assessment.[21] The study with the highest MERSQI score was one of two included studies involving students from multiple institutions and used OSCE scores to evaluate the impact of the intervention.[21] As a result, all participant data were available for analysis and student behaviour was assessed using objective, rather than self-assessed, measures. This study involved a single classroom-based interprofessional nutrition workshop integrated within the pre-clinical curricula. Features of studies achieving low quality rating scores included evaluation methods that were self-assessed, achieved learning outcomes regarding student satisfaction and attitudes only, and had a low or unreported response rate. Item-specific scores are detailed in the Supporting information (Table S2).

DISCUSSION

The present study aimed to evaluate nutrition education interventions delivered to medical students published between 2015 and 2020 and assess recent efforts in this field subsequent to publication of the prior systematic review on the topic.[15] To the best of the author's knowledge, this is the only review of undergraduate medical nutrition education interventions and their outcomes published[15] within this timeframe.

Similar to the previous review, the majority of studies were conducted in the USA and the remainder in European countries, which may mean that the interventions reviewed are not culturally applicable to other countries. The under-representation of other nations in the peer-review literature may limit the development of culturally diverse interventions and result in less appropriate approaches to nutrition education. Therefore, the recent literature base would benefit from wider global representation.

The majority of the interventions in this review were elective (optional), despite the growing consensus that nutrition education for medical students should be required in undergraduate training.[14] The study by Mota et al.[26] was the only one in this review to integrate and evaluate a required curricula unit, consisting of 75 h of nutrition education for first year medical students.[26] Medical students participating in optional interventions may represent either a more motivated or more nutritionally aware cohort, which may over- or underestimate results. Despite the centrality of nutrition to health,[14] efforts to introduce compulsory nutrition education may be hindered by an already crowded curriculum. Strategies to navigate this include establishing nutrition as an integrated theme throughout the curriculum and using the existing content to discuss the role of nutrition in health.[33] Using themes allows educators to meaningfully link different disciplines for students to appreciate the relevance of learning to their future practice.[34] However, this requires commitment from curriculum designers to support their staff and organise its delivery and evaluation.[34] Progress has been made by some UK medical schools including University College London Medical School, which has included a culinary medicine course within its core curriculum involving culinary skills training, case-based discussions and motivational interviewing role play.[35]

Most interventions included non-medical professionals as instructors ($n = 11$); however, only four were explicit in utilising IPL.[19,21,24,27] The latest BEME report on the effects of IPL found that it improves the effectiveness of educational interventions.[36] The benefits of IPL include improved interprofessional attitudes and perceptions and increased collaborative knowledge and skills.[36] In addition, the multidisciplinary nature of nutrition care and patient education is well suited to IPL. This may address concerns that faculty are not equipped to develop and deliver nutrition training when preparing students for the reality of collaborative practice.[37] This is highlighted in one of the included studies where dietitians were described as being crucial for the development and facilitation of a nutrition workshop.[21] There is also the potential to incorporate IPL with nutrition competencies to prepare students for practice in delivering high quality care and advice.[37] For an intervention to be considered as IPL, there must be an active exchange between different professionals with the aim of improving care.[36] This should be made explicit when designing and describing a multidisciplinary intervention, as highlighted by the latest systematic review of nutrition education interventions.[15]

Novel methods of teaching nutrition, including culinary medicine and student-led components, were observed in this review. Interactive cooking sessions were used in seven of the interventions, giving students a 'hands-on' learning experience termed culinary medicine. This differs from the previous review on nutrition education interventions, with only two of the 32 included studies involving a kitchen-based element.[15] Potential reasons for this increased interest may include a greater focus on prevention in policy[38] and the shift towards delivering engaging and applicable medical education.[39]

Part of the rationale behind this method is the evidence that doctors are more likely to counsel patients on lifestyle modifications if they themselves practice healthy habits.[40] Three of these interventions demonstrated improved student self-reported health behaviours.[23,25,29] For example, students participating in a multisite medical school-based teaching kitchen intervention significantly higher self-reported high and medium adherence to a Mediterranean diet compared with a control cohort (odds ratio = 1.40, 95% confidence interval = 1.07–1.84, $p = 0.015$).[25] The wider benefits of such schemes include the potential for medical students to teach patient groups in similar settings. A randomised controlled study demonstrated improved biometrics in patients with type 2 diabetes after student and faculty-led cooking classes.[41] Statistically significant changes include improvements in diastolic blood pressure (−4 vs. 7 mmHg, $p = 0.037$) and total cholesterol (−14 vs. 17 mg dl^{-1}, $p = 0.044$). Furthermore, a recent systematic review concluded that culinary interventions delivered to patients were associated with improved attitudes and a healthier dietary intake.[42] The increasing application of culinary medicine is highlighted by the recent formation of organisations such as Culinary Medicine[43] in the UK and the Teaching Kitchen Collaborative[44] in the USA.

Some interventions required the students themselves to teach peers,[18] schoolchildren[20,29,31] or families[30] about nutrition. Learning-by-teaching is a recognised method of learning supported by empirical evidence suggesting that teaching promotes cognitive benefits.[45] There are also many established benefits of specifically peer-assisted learning[46] and service-learning[47] that may extend beyond the individual. The benefits of service-learning in the identified studies include improved mentorship skills[30] and increased confidence in nutrition and obesity counselling.[29]

The heterogeneity between the identified interventions, including the content and methods, is mirrored from the previous review.[15] This is important to address so that future physicians are able to provide consistent and high-quality care to their patients. As echoed by Crowley et al.,[14] there is a need to standardise and integrate nutrition education across nations. Institutions such as the Association for Nutrition UK[48] and European Society for Clinical Nutrition and Metabolism[49] have developed guidance outlining the requirements of undergraduate nutrition training, although further action is needed to integrate these standardised objectives within medical curricula. Additionally, variations in the scope and detail of these guidelines may ultimately impact the nutrition care delivered within these regions.[50] Therefore, a 'joint international strategic approach to nutrition in medical education' has been suggested as a more consistent solution.[50]

Strengths and limitations

The strengths of this review include its systematised search and appraisal strategy. Although only English-language studies were included in this review, no studies were excluded on language alone after full-text review. A wider search of databases such as MedEdPORTAL and a grey literature search may have yielded further relevant studies. This study did not undergo double screening.

CONCLUSIONS AND RECOMMENDATIONS

This rapid review explores and summarises nutrition education interventions delivered to medical students published within the past 5 years. Heterogeneity in the methods, content and outcomes of the identified interventions was identified. This review highlights the benefits of teaching approaches including IPL and placing a focus on the student's personal health behaviours. Novel teaching methods such as culinary medicine and student-led initiatives may offer additional benefits, including to the wider community. This review highlights the need for institutions to publish and share their resources for wider global representation in the literature. Additionally, the use of validated surveys and objective assessments should be considered to improve the quality of their findings. Institutions may also consider a curricula-wide approach to integrating nutrition education using national guidance to improve standardisation of learning objectives and assessment. Future research may involve longitudinal studies to assess the long-term impact of integrated nutrition education on delivery of care and its impact on patients.

ACKNOWLEDGEMENTS

We thank Dr Carolina Rojido for her invaluable editing assistance. We also thank Dr Stephanie Bull, Alison Bethel and Amy McEwan for their timely and thoughtful advice with this review. Priya Patel and Shireen Kassam agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved and both authors were in agreement to be submitted for publication. There was no funding granted for this project.

CONFLICT OF INTERESTS

The authors declare that there are no conflicts of interest.

ETHICAL APPROVAL

No human subjects were involved in this study. This was a rapid review.

AUTHOR CONTRIBUTIONS

Priya Patel contributed from conception to the design and main body of the paper. Shireen Kassam contributed significantly to the main body of the paper, particularly with development of the introduction and discussion. Priya Patel and Shireen Kassam reviewed and edited several drafts of the paper.

TRANSPARENCY DECLARATION

The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

ORCID

Priya Patel http://orcid.org/0000-0002-0740-1099
Shireen Kassam https://orcid.org/0000-0002-6173-3326

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1111/jhn.12972.

REFERENCES

1. GBD 2017 Diet collaborators. Health effects of dietary risks in 195 countries, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2019;393:1958–72.
2. Clinton SK, Giovannucci EL, Hursting SD. The World Cancer Research Fund/American Institute for Cancer Research third expert report on diet, nutrition, physical activity, and cancer: impact and future directions. J Nutr. 2020;150:663–71.
3. Estruch R, Ros E, Salas-Salvadó J, Covas MI, Corella D, Arós F, et al. Primary prevention of cardiovascular disease with a Mediterranean diet. N Eng J of Med. 2013;368:1279–90.
4. Kahleova H, Levin S, Barnard N. Cardio-metabolic benefits of plant-based diets. Nutrients. 2017;9:848.
5. World Health Organisation Noncommunicable diseases country profiles: United Kingdom. 2018. [cited 2018 Sep]. Available from: https://www.who.int/nmh/countries/gbr_en.pdf
6. World Health Organisation Noncommunicable diseases country profiles: United States of America. 2018. [cited 2018 Sep]. Available from: https://www.who.int/nmh/countries/usa_en.pdf
7. General Medical Council & Outcomes for graduates 2020. [cited 2020 Feb 25]. Available from: https://www.gmc-uk.org/education/standards-guidance-and-curricula/standards-and-outcomes/outcomes-for-graduates/outcomes-for-graduates
8. GovTrack.us H.R. 1888 — 116th Congress: ENRICH Act. 2021. [cited 2019 Mar 26]. Available from: https://www.govtrack.us/congress/bills/116/hr1888
9. AAMC Endorses Bill to Enhance Medical School Curricula in Nutrition 2019. [cited 2019 Dec 5]. Available from: https://www.aamc.org/advocacy-policy/washington-s/aamc-endorses-bill-enhance-medical-school-curricula-nutrition
10. O'hearn M, Liu J, Cudhea F, Micha R, Mozaffarian D. Coronavirus disease 2019 hospitalizations attributable to cardiometabolic conditions in the United States: a comparative risk assessment analysis. J Am Heart Assoc. 2021;10:e019259.
11. Williamson EJ, Walker AJ, Bhaskaran K, Bacon S, Bates C, Morton CE, et al. Factors associated with COVID-19-related death using OpenSAFELY. Nature. 2020;584:430–6.
12. Macaninch E, Buckner L, Amin P, Broadley I, Crocombe D, Herath D, et al. Time for nutrition in medical education. BMJ Nutr Prev Health. 2020;3:40.
13. Ganis L, Christides T. Are we neglecting nutrition in UK medical training? A quantitative analysis of nutrition-related education in postgraduate medical training curriculums. Nutrients. 2021;13(3):957.
14. Crowley J, Ball L, Hiddink GJ. Nutrition in medical education: a systematic review. Lancet Planet Health. 2019;3:e379–89.
15. Dang TM, Maggio LA. Supporting the call to action: a review of nutrition educational interventions in the health professions literature and MedEdPORTAL. Acad Med. 2017;92:403–16.
16. Hammick M, Dornan T, Steinert Y. Conducting a best evidence systematic review. Part 1: from idea to data coding. BEME Guide No. 13. Med Teach. 2010;32:3–15.
17. Reed DA, Cook DA, Beckman TJ, Levine RB, Kern DE, Wright SM. Association between funding and quality of published medical education research. JAMA. 2007;298:1002–9.
18. Baute V, Carr AD, Blackwell JN, Carstensen ER, Chhabra P, Porter LC, et al. Incorporating formal nutrition education into a medical school curriculum: a student-initiated lecture series. Am J Med. 2017;130:623–5.
19. Berz J, Donovan K, Eyllon M. An interprofessional nutrition education session for senior medical students on evidence-based diet patterns and practical nutrition tips. MedEdPORTAL. 2020;16:10876.
20. Broad J, Wallace M. Nutrition and public health in medical education in the UK: reflections and next steps. Public Health Nutr. 2018;21:2523–5.
21. Cavuoto Petrizzo M, Block L, Olvet DM, Sheridan EM, Dougherty R, Whitson M, et al. Implementation of an interprofessional nutrition workshop to integrate nutrition education into a preclinical medical school curriculum. J Am Coll Nutr. 2020;40(2):111–8.
22. Coppoolse HL, Seidell JC, Dijkstra SC. Impact of nutrition education on nutritional knowledge and intentions towards nutritional counselling in Dutch medical students: an intervention study. BMJ Open. 2020;10:034377.
23. Flynn MM, George P, Schiffman FJ. Food is medicine: using a 4-week cooking program of plant-based, olive oil recipes to improve diet and nutrition knowledge in medical students. Med Sci Educ. 2019;29:61–6.
24. Jacob M, Stewart P, Medina-Walpole A, Fong CT. A culinary laboratory for nutrition education. Clin Teach. 2016;13:197–201.
25. Monlezun DJ, Dart L, Vanbeber A, Smith-Barbaro P, Costilla V, Samuel C, et al. Machine learning-augmented propensity score-adjusted multilevel mixed effects panel analysis of hands-on cooking and nutrition education versus traditional curriculum for medical students as preventive cardiology: multisite cohort study of 3,248 trainees over 5 years. BioMed Res Int. 2018;2018:5051289.
26. Mota IB, Castelo I, Morais J, Anjos M, Costa JP, Dias M, et al. Nutrition education in Portuguese medical students: impact on the attitudes and knowledge. Acta Med Port. 2020;33:246–51.
27. Pang B, Memel Z, Diamant C, Clarke E, Chou S, Gregory H. Culinary medicine and community partnership: hands-on culinary skills training to empower medical students to provide patient-centered nutrition education. Medl Educ Online. 2019;24:1630238.
28. Ramsetty A, Adams C, Berini C, Watson KH. Medical student attitudes on nutrition counseling after implementation of a novel curricular activity. J Am Coll Nutr. 2020;39:333–7.
29. Ring M, Cheung E, Mahadevan R, Folkens S, Edens N. Cooking up health: a novel culinary medicine and service learning elective for health professional students. J Altern Complement Med. 2019;25:61–72.
30. Ronecker J, Liu J, VanGarsse A, Newman R. Coaching, health, and movement program (Champs) taught by medical students: a didactic curriculum and program analysis. Osteopath Fam Physician. 2019;11:12–7.
31. Rothman JM, Bilici N, Mergler B, Schumacher R, Mataraza-Desmond T, Booth M, et al. A culinary medicine elective for

clinically experienced medical students: a pilot study. J Altern Complement Med. 2020;26:636–44.
32. Shafto K, Breen J, Decker D. Reimagining nutrition education in a teaching kitchen. findings from a pilot study. Minn Med. 2016; 99:44–5.
33. Kushner RF, Van Horn L, Rock CL, Edwards MS, Bales CW, Kohlmeier M, et al. Nutrition education in medical school: a time of opportunity. Am J Clin Nutr. 2014;99:1167S–73S.
34. Malik AS, Malik RH. Twelve tips for developing an integrated curriculum. Med Teach. 2011;33:99–104.
35. Xie JY, Abramovich N, Burridge J, Jaffee A, Broadley I. Nutrition education in core medical curricula: a call to action from tomorrow's doctors. Future Healthc J. 2021;8:19–21.
36. Reeves S, Fletcher S, Barr H, Birch I, Boet S, Davies N, et al. A BEME systematic review of the effects of interprofessional education: BEME Guide No. 39. Med Teach. 2016;38:656–68.
37. DiMaria-Ghalili RA, Edwards M, Friedman G, Jaferi A, Kohlmeier M, Kris-Etherton P, et al. Capacity building in nutrition science: revisiting the curricula for medical professionals. Ann N Y Acad Sci. 2013;1306:21–40.
38. National Health Service The NHS long term plan. 2019. [cited 2019 Jan]. Available from: https://www.longtermplan.nhs.uk/
39. Buja LM. Medical education today: all that glitters is not gold. BMC Med Educ. 2019;19:110.
40. Oberg EB, Frank E. Physicians' health practices strongly influence patient health practices. J R Coll Physicians Edinb. 2009;39:290–1.
41. Monlezun DJ, Kasprowicz E, Tosh KW, Nix J, Urday P, Tice D, et al. Medical school-based teaching kitchen improves HbA1c, blood pressure, and cholesterol for patients with type 2 diabetes: results from a novel randomized controlled trial. Diabetes Res Clin Pract. 2015;109:420–6.
42. Hasan B, Thompson WG, Almasri J, Wang Z, Lakis S, Prokop LJ, et al. The effect of culinary interventions (cooking classes) on dietary intake and behavioral change: a systematic review and evidence map. BMC Nutr. 2019;5:29.
43. Culinary Medicine UK. 2021. Available from: https://culinarymedicineuk.org
44. Teaching Kitchen Collaborative. 2021. Available from: https://teachingkitchens.org
45. Duran D. Learning-by-teaching. Evidence and implications as a pedagogical mechanism. Innov Educ Teach Int. 2017;54:476–84.
46. Yu T-C, Wilson NC, Singh PP, Lemanu DP, Hawken SJ, Hill AG. Medical students-as-teachers: a systematic review of peer-assisted teaching during medical school. Adv Med Educ Pract. 2011;2:157–72.
47. Stewart T, Wubbena ZC. A systematic review of service-learning in medical education: 1998–2012. Teach Learn Med. 2015;27: 115–22.
48. Association for Nutrition UK. Undergraduate curriculum in nutrition for medical doctors. 2021. [cited 2021 Oct]. Available from: https://www.associationfornutrition.org/wp-content/uploads/2021/10/2021-UK-Undergraduate-Curriculum-in-Nutrition-for-Medical-Doctors-FINAL.pdf
49. Cuerda C, Muscaritoli M, Donini LM, Baqué P, Barazzoni R, Gaudio E, et al. Nutrition education in medical schools (NEMS). An ESPEN position paper. Clin Nutr. 2020;39: 2938–9.
50. Crowley J, Ball L, Laur C, Wall C, Arroll B, Poole P, et al. Nutrition guidelines for undergraduate medical curricula: a six-country comparison. Adv Med Educ Prac. 6:127–33.

AUTHOR BIOGRAPHIES

Priya Patel, MSc, is a final year medical student.

Dr Shireen Kassam, MBBS, FRCPath, PhD, is a Consultant Haematologist and Lifestyle Medicine Physician. Founder and Director of Plant-Based Health Professionals UK.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Patel P, Kassam S. Evaluating nutrition education interventions for medical students: A rapid review. J Hum Nutr Diet. 2022;35:861–871. https://doi.org/10.1111/jhn.12972