JAN MAKURAT

Impact of Lunch Provision on the Nutritional and Health Status of Garment Workers in Cambodia

DISSERTATION

for the degree of Dr. oec. troph.
at the Faculty of Agricultural Sciences,
Nutritional Sciences, and Environmental Management
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Submitted by

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Giessen, 2018

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"**I declare** that the dissertation here submitted is entirely my own work, written without any illegitimate help by any third party and solely with materials as indicated in the dissertation. I have indicated in the text where I have used texts from already published sources, either word for word or in substance, and where I have made statements based on oral information given to me. At all times during the investigations carried out by me and described in the dissertation, I have followed the principles of good scientific practice as defined in the "Statutes of the Justus Liebig University Giessen for the Safeguarding of Good Scientific Practice."

Preface

The idea for the present dissertation came up in summer/autumn 2013, at a time when thousands of Cambodian garment workers participated in numerous strikes and demonstrations, demanding higher wages and better working conditions. From that point on, the media, unions, and various non-governmental organizations started to report on the overall poor nutrition and health of workers, given their very low salaries and the frequent onset of on-the-job faintings. The access to lunch provision via staff canteens, which is rare at Cambodian garment factories to the present day, has been suggested as an appropriate and suitable intervention.

The underlying trial to this thesis, the LUPROGAR study (Lunch Provision in Garment Factories), was conceptualized at the beginning of 2014, thanks to the support from Prof. Michael B. Krawinkel (Institute of Nutritional Sciences, JLU Giessen). The funding was provided by the German Federal Ministry of Economic Cooperation and Development (BMZ) at the end of 2014. The corresponding field work in Cambodia was implemented throughout the year 2015.

First of all, I would like to express my sincere thanks to my advisor and the principal investigator of the LUPROGAR study, Prof. Michael B. Krawinkel, for his professional guidance and widespread backing within the last years. The common time we have spent together during detailed discussions and planning was very much instructive and helped to overcome the various obstacles during the preparation of this work. I would like to thank him, especially for his patience, his encouragement, and for allowing me to be involved in all aspects of the LUPROGAR project.

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The LUPROGAR study was conducted in close collaboration with Dr. Chhoun Chamnan (Department of Fisheries Post-Harvest Technologies and Quality Control, Fisheries Administration, Phnom Penh, Cambodia) and Dr. Frank T. Wieringa (Institut de Recherche pour le Développement, Montpellier, France). I thank both of them for their overall support as co-investigators and co-advisors.

The preparation of this thesis would have not been possible without the outstanding support of Khov Chhay (Managing Director) and the management of Apsara Garment Co. Ltd., Phnom Penh, Cambodia, who had a great interest in the LUPROGAR study and helped to implement the project at all levels. At this place, I also want to thank all study participants for their willingness and patience to participate in the LUPROGAR trial.

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I have received tremendous assistance from colleagues at the Department of Fisheries Post-Harvest Technologies and Quality Control, Fisheries Administration, Phnom Penh, Cambodia, notably from Dr. Khov Kuong, Sok Seyha, Lach Thea, Sok Daream, Dy Moeunnary, Yo Vichny, and Dr. Marion Fiorentino. I have had a great time with them in Phnom Penh. Moreover, I have also received support from Hanna Friedrich, Natalie Becker, Eleonore C. Kretz, and Dr. Aarati Pillai (all at the Institute of Nutritional Sciences, JLU Giessen) during field work and/or data analysis. Their contribution is highly appreciated.

I also like to thank the entire workgroup International Nutrition at the JLU Giessen, especially Daniela Rühl and Petra Andreas for the great administrative support, Dr. Johannes Herrmann for statistical advice, and Dr. Sandra Habicht and Dr. Christine Ludwig for their patience in talking through every detailed aspect of the study implementation and analysis.

Last but not least, I would like to thank my family and friends for always encouraging me in the completion of this dissertation. Adriana Sanz Mirabal managed to follow me on my academic journey for the last years. My heartfelt thanks to her for her permanent endorsement and the best proofreading.

Jan Makurat
Lübeck, October 2018

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II. Jan Makurat, Aarati Pillai, Frank T. Wieringa, Chhoun Chamnan and Michael B. Krawinkel. **Estimated Nutritive Value of Low-Price Model Lunch Sets Provided to Garment Workers in Cambodia**. *Nutrients* **2017**, 9, 782; doi: 10.3390/nu9070782.

III. Jan Makurat, Eleonore C. Kretz, Frank T. Wieringa, Chhoun Chamnan and Michael B. Krawinkel. **Dietary Diversity in Cambodian Garment Workers: The Role of Free Lunch Provision**. *Nutrients* **2018**, 10, 1010; doi: 10.3390/nu10081010.

IV. Jan Makurat, Natalie Becker, Frank T. Wieringa, Chhoun Chamnan and Michael B. Krawinkel. **Impact of Lunch Provision on Anthropometry, Hemoglobin, and Micronutrient Status of Cambodian Garment Workers: Exploratory Randomized Controlled Trial**. *Unpublished manuscript* **2018**.

Abbreviations

BMI: Body mass index

CSR: Corporate Social Responsibility

DGLV: Dark green leafy vegetables

EU: European Union

FAO: Food and Agriculture Organization of the United Nations

FER: Ferritin

Hb: Hemoglobin

ILO: International Labour Organization of the United Nations

Kcal: Kilocalories

LUPROGAR: Lunch Provision in Garment Factories

MUAMC: Mid-upper arm muscle circumference

NGO: Non-governmental organization

RAE: Retinol activity equivalent

RBP: Retinol binding protein

RDA: Recommended dietary allowance

sTfR: Soluble transferrin receptor

TSF: Triceps skinfold thickness

UK: United Kingdom

USD: United States Dollar

USA: United States of America

VitA: Vitamin A

VitB12: Vitamin B12

VitC: Vitamin C

VitD: Vitamin D

WDDS: Women's dietary diversity score

WHO: World Health Organization of the United Nations

Summary

Although concerns about the nutritional and health status of Cambodian garment workers do exist, data are still sparse. The establishment of staff canteens in garment factories serving free lunch has been proposed as a suitable intervention to improve nutrition and health of workers. However, trials that verify this hypothesis are missing and information is lacking on exemplary meals, their nutritive value, and their costs.

The objectives of the present thesis are: 1) to examine the nutritional, hemoglobin (Hb), and micronutrient status of female workers employed by a garment factory in Phnom Penh, Cambodia; 2) to assess the nutritive value of low-price model lunch sets provided to garment workers within the Lunch Provision in Garment Factories study (LUPROGAR); 3) to compare food intake between garment workers with and without access to LUPROGAR's model lunch provision; and 4) to determine the impact of LUPROGAR's model lunch provision on anthropometry, Hb, and micronutrient status of female Cambodian garment workers.

The LUPROGAR study was an exploratory randomized controlled trial implemented at a garment factory in Phnom Penh, Cambodia. Female workers (nulliparous, non-pregnant) were recruited and randomly allocated into an intervention arm (six-month free model lunch provision through a newly established canteen during workdays) and a control arm. Exemplary low-price lunch sets (~700 kcal on average, biweekly menu) included diverse local dishes prepared by an established local caterer. At baseline and after five months of lunch provision, anthropometric measurements (body mass index (BMI), weight, triceps skinfold thickness (TSF), and mid-upper arm circumference (MUAMC)) were performed and blood samples were taken to obtain results on Hb, serum ferritin (FER) and soluble transferrin receptor (sTfR), serum retinol binding protein (RBP), serum folate, and serum vitamin B12 (VitB12) concentrations. Dietary intake on workdays was assessed at baseline and at two follow-up interviews during the lunch provision period (first follow-up at two and a half months and second follow-up at five months) using the Food and Agricultural Organization (FAO) guideline on recording individual dietary diversity. At the canteen, dish samples were collected repeatedly to examine mean serving sizes of individual ingredients. Food composition tables and NutriSurvey software were used to assess mean amounts and contributions to recommended dietary allowances (RDAs) or adequate intake of energy, macronutrients, dietary fiber, vitamin C (VitC), iron, vitamin A (VitA), folate, and VitB12.

223 women were recruited (n=112 control and n=111 intervention). 172 (n=86 in each arm) completed the study. Baseline prevalence of underweight, anemia, depleted iron stores, and marginal iron stores, were 31%, 27%, 22%, and 47%, respectively. Subjects were not affected by frank VitA, folate, or VitB12 deficiency, whereas ~30% showed a marginal folate status. On average, LUPROGAR's model lunch sets provided roughly one third of RDA or adequate intake of energy, carbohydrates, fat, and dietary fiber. Contribution to RDA of protein was high (46% RDA). Lunches contained a high mean share of VitC (159% RDA), VitA (66% RDA), and folate (44% RDA), but were rather low in VitB12 (29% RDA) and iron (20% RDA). Intervention subjects on average visited the canteen on 85% of the intervention days. Lunch provision resulted in a more frequent consumption of dark green leafy vegetables, VitA-rich fruits, other fruits, and oils and fats during lunch breaks. In contrast, flesh meats, legumes, nuts and seeds, as well as sweets, were eaten at a lower frequency. Except for a higher consumption rate of VitA-rich fruits and a lower intake frequency of sweets, lunch provision had a less clear impact on total 24-h intake from different food groups and was not associated with a higher women's dietary diversity score. Overall, mean changes in anthropometric variables, Hb, and serum RBP were marginal and not significant among intervention subjects. Mean serum folate concentration increased by +1.1 ng/mL (-0.02, 2.2) (p=0.054), representing a marginally significant positive intervention effect. On the other hand, mean serum FER decreased by -6.6 µg/L (-11.9, -1.3) (p=0.015). A secondary subgroup analysis prompts that effects are differently pronounced according to the baseline status of workers.

Young female garment workers in Cambodia are identified as a group with an elevated risk for nutritional deficiencies. Therefore, strategies need to be developed for improving their nutritional, Hb, micronutrient, and health status. LUPROGAR's exemplary low-price lunch sets for garment workers matched recommendations regarding their contribution to RDA's of caloric content and macronutrient composition for sources of energy intake. Future model lunch sets for this group of women could incorporate some organ meats to increase the provision of iron. On the other hand, it is considered that LUPROGAR's model lunch sets contained beneficial and adequate amounts of VitC, VitA, folate and VitB12, on average. Consequently, meal provision via staff canteens is expected to bear the potential to improve food security of workers, approximately at costs of less than 1 USD/person/day (at large scale). A more gap-oriented design of the lunch sets taking into account underutilized foods and the nutritional status of the workers is recommended for

increasing their dietary diversity. Moreover, skipping of meals in workers with access to a staff canteen should be closely monitored in order to avoid unfavorable dietary changes. Distinct positive effects from lunch provision on anthropometry, Hb, and micronutrient status, can solely be expected in malnourished individuals. It is suggested that similar but larger trials, which include lunch sets adapted to the concrete needs of workers affected by underweight, anemia, and/or definite micronutrient deficiencies, should be performed. The overall findings from this study should have practical implications for the design and implementation of subsequent studies, lunch programs, and further strategies aiming at the improvement of the nutritional and health status of female garment workers in Cambodia.

1. Introduction[a]

Background

The first garment factories were set up in Cambodia in the early 1990s by foreign investments [5,6]. Following a lasting period of civil war, investors were attracted by the steady supply of young labor force and the relatively low wage rates [5,6]. Cambodia's garment industry has grown steadily over the past 25 years and more than 600 export-oriented factories operate at present, accounting for two-thirds of the country's annual merchandise exports [7]. Major destinations for the garments produced are the EU and the USA [7]. Most of the factories are located in and around Phnom Penh, the capital of Cambodia, and they are still owned by foreign investors [5,6,8]. They usually implement low value-added activities and continue to depend on cheap labor [5,6]. About 90% of their 670,000 employees are female, generally young women with a poor school education, who migrate from low-income rural households [7,9,10]. For the majority of them it is their first full-time job [11].

Since 2013, succeeding a substantial increase in strikes and demonstrations, the legal minimum wage for Cambodian garment workers has been rising, changing from 80 USD/month to 153 USD/month in 2017[b] [7]. Nevertheless, workers still heavily rely on additional income from bonuses, allowances, and overtime work [7,10–12]. A large share of the finances made while working in the factories, often more than 50% of the total salary, is budgeted to support family members, which has a considerable anti-poverty effect in rural areas [10–12].

Given the very low disposable finances of Cambodian garment workers, concerns about their nutritional situation were raised some time ago [11,12]. Socio-economic surveys concluded that an appropriate diet with respect to quantity and quality is likely to be out of reach, considering the thrifty sum of about 1.5 USD/day spent by workers on food [10–12]. The expenditure on food is a result of extreme budgeting and saving measures which even involve skipping of meals [10–12]. Despite the alarming situation, sound data regarding the dietary intake and the nutritional status of Cambodian garment workers are scarce to non-existent. Based on a small cross-sectional survey

[a] Parts of this chapter are based on sections from papers related to this thesis [1–4].
[b] In 2015, at the time of study implementation, the minimum wage was 128 USD/month.

in 2013[c], NGOs reported a prevalence of 36% underweight among female workers [10]. The nutritional situation of workers has become a sensitive topic in national and international media, especially as it has been linked to the faintings frequently reported from the factories [10]. However, the action undertaken in the recent years has been limited. A rise in salary, as seen in recent years, will not automatically lead to improved nutrition among the workers, given the interim significant increase in Cambodian consumer prices and workers' persistent contribution to the social securing of rural family members.

Only a few valid studies[d] examined the nutritional situation of garment workers in other countries (see Table 1). Almost all surveys were implemented in Bangladesh, a country known to have a large export-oriented garment industry, employing female workers at comparable conditions. Anthropometric measurements showed that thinness (low weight for height) and stunting (low height for age), both indicators for chronic undernutrition, are prevalent among young garment workers in Bangladesh [13,14]. Moreover, the high prevalence of anemia and several micronutrient deficiencies (iron, vitamin A (VitA), folate, vitamin B12 (VitB12) and vitamin D (VitD)) were of concern [13–17]. The dietary intake of protein, iron, VitA, vitamin C (VitC), calcium, and several B-vitamins was shown to be low, combined with a poor intake of eggs, milk, meat, organ meats, and green leafy vegetables [13,14]. Supplementation with VitD and calcium or multiple micronutrients was the only verified intervention and improved the VitD status of Bangladeshi workers [18].

Table 1. Research studies on the dietary intake and/or nutritional status of female garment workers.

Reference	Location	Study design	Age of participants (years)	Sample size (*n*)
Ahmed et al., 1997 [13]	Dhaka, Bangladesh	Cross-sectional	12-19	388
Ronnenberg et al., 2000 [15]	Anqing, China	Prospective	21-34	563
Khan & Ahmed, 2005 [14]	Dhaka, Bangladesh	Cross-sectional	14-19	1211
Islam et al., 2008 [16]	Dhaka, Bangladesh	Cross-sectional	18-36	200
Islam et al., 2010 [18]	Dhaka, Bangladesh	Intervention	18-36	200
Islam et al., 2013 [17]	Dhaka, Bangladesh	Cross-sectional	18-36	198

[c] At study planning, this was the only report providing data on the nutritional status of Cambodian garment workers.
[d] Including studies available before study implementation.

In sum, the topic "nutrition of garment workers" did not gain much research interest until now, even though it is known that millions of workers, especially young disadvantaged women, are employed by the global export-oriented garment industry, partly under very harsh conditions, which are assumed to have a negative impact on their nutrition and health status. Indeed, malnutrition among women in reproductive age (with respect to underweight, anemia, and micronutrient deficiencies) is associated with numerous poor health-related outcomes, such as impaired cognition, reduced work capacity and impaired immune responses, leading to lowered resistance to infections [19–21]. During pregnancy, it is also associated with increased maternal morbidity and mortality, low birth weight, premature delivery and increased fetal and neonatal deaths [19–21].

Scope of this thesis

In spite of a rising number of nutrition-related research projects in Cambodia for the last years, there is still sparse information on the nutritional and health situation of the country's garment workers. Valid data are strongly needed to empower all actors along the Cambodian garment industry to make informed choices and act accordingly. The present thesis aims at counteracting this lack of information.

The core theme of the current work is to examine the effects of a model low-price lunch provision on the nutritional and health status of Cambodian garment workers. The setup of staff canteens serving lunch in Cambodian garment factories has been suggested as an adequate intervention to improve nutrition and health of workers, to reduce absenteeism, and thus to actually increase productivity [22]. Yet, convincing trials that verify these hypotheses are lacking and an intervention has to be tested before being implemented on a larger scale.

The vast majority of factories do not hold a canteen, with the operation costs being the most critical factor for factory owners [22]. At present, there is no national legislation obliging factory owners to operate canteens or to provide meals in any other way. Furthermore, national guidelines on meal provision in garment factories do not exist. Consequently, detailed information is missing on exemplary meals/menus, their costs, their nutritive value, and their potential contribution towards recommended dietary allowances (RDA's).

The LUPROGAR study

The Lunch Provision in Garment Factories (LUPROGAR) study was a factory-based exploratory randomized controlled trial. The trial was implemented in 2015 at Apsara Garment Co. Ltd. (selected purposely, ~1,300 employees), an export-oriented garment factory located in the suburban commune Chom Chau of Phnom Penh. Conditions of employment were assumed to be similar to overall working conditions in the Cambodian garment sector. The study population included young non-pregnant nulliparous females employed by Apsara Garment Co. Ltd.. Figure 1 illustrates the initially planned study procedure[e]. The study used an explorative approach to estimate an appropriate sample size, since both data on the nutritional status of Cambodian garment workers and exemplary data on the effects of lunch provision in this context were largely missing at time of trial implementation. In brief, workers who signed the informed consent were invited to the enrollment and baseline assessment (end of April 2015), which included a clinical screening. Enrolled participants were individually allocated in equal shares into an intervention arm (access to six-month free lunch provision through a newly established canteen during workdays) and a control arm (equal monetary compensation at the end of the trial).

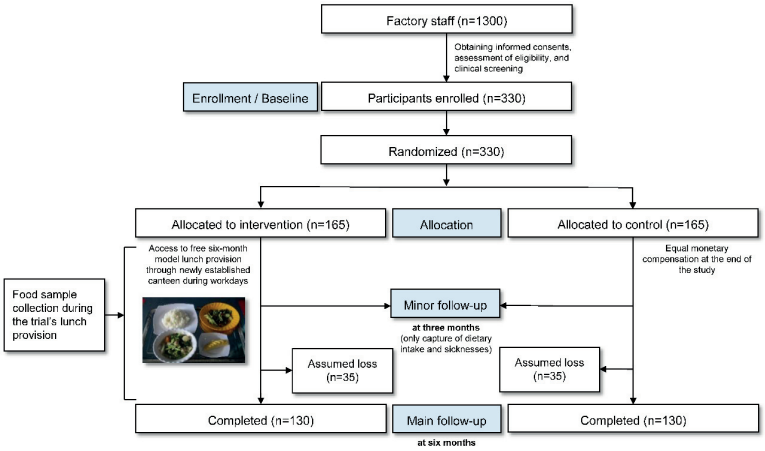

Figure 1. Flow diagram of the trial (initially planned procedure).

[e] Changes to the planned trial procedure were required upon implementation. The endline assessment was preponed by one month in order to minimize the amount of dropouts (see chapter 5 & 6).

A temporary canteen was set up in a roofed area at the factory site specifically for this trial. The factory was previously not operating a staff canteen. Full model lunch sets were provided in collaboration with an established Phnom Penh-based canteen service provider (Hagar Catering and Facilities Management Ltd.). Lunches were planned to provide about one-third of the RDA for non-pregnant women aged 19-30 years old (total ~700 kcal) [23]. Based on these standards, a biweekly low-price menu was outlined in agreement with the caterer. Focus was laid on acceptable Cambodian dishes, using local foods and ensuring dietary variety by providing cereals, various vegetables, animal source foods, and fresh fruits on a daily basis. Lunch provision for the intervention group was carried out by the caterer for six months from beginning of May till end of October 2015. Access to the study canteen was voluntary and recorded daily. Additional information on exact costs, components and ingredients, serving sizes, and corresponding nutritive value of single lunch sets can be found in chapter 3.

Table 2 provides an in-detail overview on the data that have been collected within the trial. While the entire data set (anthropometry, blood levels, dietary intake, self-reported morbidity, and handgrip strength) has been obtained at baseline, as well as at endline, the minor follow-up (midline) only involved the assessment of dietary intake and self-reported sicknesses. Within the course of the six-month lunch provision, food samples were taken directly from the service counter (non-systematic convenience sampling) to determine the nutritive value of LUPROGAR's model lunch sets considering the actual portion sizes. Given the exploratory trial design, the main outcomes were determined as changes in body-mass-index (BMI), weight, triceps skinfold thickness (TSF), and mid-upper arm muscle circumference (MUAMC) (as anthropometric variables), as well as changes in hemoglobin (Hb) and serum ferritin (FER), soluble transferrin receptor (sTfR), retinol-binding protein (RBP), folate, and VitB12 concentrations (as Hb and micronutrient status) of participants at endline (planned at six months). Minor outcomes were planned as changes in women's dietary diversity score (WDDS), in the prevalence of self-reported sicknesses, as well as in maximum handgrip strength. The latter two outcomes are not included in the current thesis.

Table 2. Data collected within the LUPROGAR trial.

Data	Method	Baseline	Midline Minor follow-up	Endline Main follow-up	Main outcome	Minor outcome
Background information & socio-economic status	Semi-structured questionnaire	**X**	-	-	NA	NA
Anthropometry	Various anthropometric measurements	**X**	-	**X**	Change in BMI (kg/m^2), weight (kg), TSF (mm), and MUAMC (cm)	-
Hemoglobin status	Blood sampling	**X**	-	**X**	Change in Hb (g/dL)	-
Micronutrient status (Iron, VitA, folate, and VitB12)	Blood sampling	**X**	-	**X**	Change in serum FER (µg/L), sTfR (mg/L), RBP (µmol/L), folate (ng/mL), and VitB12 (pmol/L)	-
Dietary intake	Qualitative 24-h recall	**X**	**X**	**X**	-	Change in WDDS
Illness history and sick leave [1]	Semi-structured questionnaire	**X**	**X**	**X**	-	Change in prevalence of self-reported respiratory tract infections, fever, and diarrhea
Handgrip strength [1]	Handgrip dynamometer	**X**	-	**X**	-	Change in maximum handgrip strength (kg)
Nutritive value of the trial's model lunch sets	Food sample collection during lunch provision	**Continuously**			NA	NA

[1] Evaluation not included in the current thesis. NA: Not applicable; BMI: Body-mass-index; TSF: Triceps skinfold thickness; MUAMC: Mid-upper arm muscle circumference; Hb: Hemoglobin; FER: ferritin; sTfR: Soluble transferrin receptor; RBP: Retinol-binding protein; WDDS: Women´s dietary diversity score.

Objectives of this thesis

The aims of the present thesis are: 1) to examine the nutritional, Hb, and micronutrient status of female workers employed by a garment factory in Phnom Penh, Cambodia; 2) to assess the nutritive value of LUPROGAR's model lunch sets provided to workers; 3) to compare food consumption between study subjects with and without access to LUPROGAR's model lunch provision; and 4) to determine the impact of LUPROGAR's model lunch provision on anthropometry, Hb, and micronutrient status of female garment workers. Each objective has been linked to a paper.

Although the emphasis of this thesis is on the impact of lunch provision, LUPROGAR's baseline data have been used to provide a comprehensive overview on the status of the study population, especially on the prevalence of underweight, anemia, micronutrient deficiencies, and sicknesses and sick leave. Moreover, this first paper also examines whether the BMI of participants is related to their Hb and/or micronutrient status (chapter 2).

In order to interpret intervention results, detailed data regarding the composition and nutritive value of LUPROGAR's model lunch provision were needed. Consequently, dish samples were collected repeatedly during the intervention to examine the mean serving sizes of individual ingredients. In this second essay, data were then used to assess mean amounts and contributions to RDA's or adequate intake of energy, macronutrients, dietary fiber, VitC, iron, VitA, folate and VitB12. Furthermore, the second paper gives an overview on the overall setup of the staff canteen, the associated costs, and the exact model menu (chapter 3).

The third paper focused on the comparison of the dietary intake (at lunch and in total over 24 h) of participants with (intervention) and without access (control) to LUPROGAR's model lunch provision. Such data were likewise needed to facilitate the interpretation of the impact on the nutritional, Hb, and micronutrient status of workers. The frequency of consumption of food groups on workdays was assessed by qualitative 24-h recalls at baseline and twice at follow-ups during the period of lunch provision using the Food and Agricultural Organization (FAO) guideline on assessing women's dietary diversity (chapter 4).

The last paper contains an extensive evaluation of the actual impact of the model lunch provision on anthropometry, Hb, and micronutrient status of study subjects. It closely follows the CONSORT recommendation for the reporting of randomized controlled trials and therefore provides a detailed overview on the exact study procedures and main study results. Moreover, a secondary analysis has been included to estimate intervention effects in subgroups, based on the assumption that effects differ according to the baseline status (chapter 5).

The discussion chapter puts the individual research results into a wider context. This chapter concludes with the study limitations, as well as with recommendations for stakeholders along the Cambodian garment sector and subsequent related research projects (chapter 6).

References

1. Makurat, J.; Friedrich, H.; Kuong, K.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Nutritional and micronutrient status of female workers in a garment factory in Cambodia. *Nutrients* **2016**, 8, 694.
2. Makurat, J.; Pillai, A.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Estimated nutritive value of low-price model lunch sets provided to garment workers in Cambodia. *Nutrients* **2017**, 9, 782.
3. Makurat, J.; Kretz, E.C.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Dietary diversity in Cambodian garment workers: the role of free lunch provision. *Nutrients* **2018**, 10, 1010.
4. Makurat, J.; Becker, N.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Impact of lunch provision on anthropometry, hemoglobin, and micronutrient status of Cambodian garment workers: exploratory randomized controlled trial. *Unpublished manuscript* **2018**.
5. Bargawi, O. *Cambodia's Garment Industry - Origins and Future Prospects*; Overseas Development Institute: London, UK, **2005**.
6. Asuyama, Y.; Neou, S. How has the Cambodian garment industry evolved? In *Dynamics of the Garment Industry in Low-Income Countries: Experience of Asia and Africa*; Fukunishi, T., Ed.; Japan External Trade Organization: Chiba, Japan, **2012**.
7. International Labour Organization. *Cambodian Garment and Footwear Sector Bulletin. Issue 7. How has garment workers' pay changed in recent years?*; International Labour Organization: Phnom Penh, Cambodia, **2018**.
8. International Labour Organization. *Cambodian Garment and Footwear Sector Bulletin. Issue 6. What explains strong export and weak employment figures in the Cambodian garment sector?*; International Labour Organization: Phnom Penh, Cambodia, **2017**.
9. International Labour Organization. *Cambodian Garment and Footwear Sector Bulletin. Issue 5. Recent trade policy developments and possible implications for Cambodia's garment and footwear sector*; International Labour Organization: Phnom Penh, Cambodia, **2017**.
10. McMullen, A. *Shop`til They Drop. Fainting and Malnutrition in Garment Workers in Cambodia*; Labour Behind the Label & Community Legal Education Centre: Phnom Penh, Cambodia, **2013**.
11. International Labour Organization; World Bank. *Cambodia. Women and Work in the Garment Industry*; International Labour Organization: Phnom Penh, Cambodia, **2006**.

12. Kang, C.; Liv, D. *Living Wage Survey for Cambodia's Garment Industry*; Cambodia Institute of Development Study: Phnom Penh, Cambodia, **2009**.
13. Ahmed, F.; Hasan, N.; Kabir, Y. Vitamin A deficiency among adolescent female garment factory workers in Bangladesh. *European Journal of Clinical Nutrition* **1997**, 51, 698–702.
14. Khan, M.R.; Ahmed, F. Physical status, nutrient intake and dietary pattern of adolescent female factory workers in urban Bangladesh. *Asia Pacific Journal of Clinical Nutrition* **2005**, 14, 19–26.
15. Ronnenberg, A.G.; Goldman, M.B.; Aitken, I.W.; Xu, X. Anemia and deficiencies of folate and vitamin B-6 are common and vary with season in Chinese women of childbearing age. *The Journal of Nutrition* **2000**, 130, 2703–2710.
16. Islam, M.Z.; Shamim, A.A.; Kemi, V.; Nevanlinna, A.; Akhtaruzzaman, M.; Laaksonen, M.; Jehan, A.H.; Jahan, K.; Khan, H.U.; Lamberg-Allardt, C. Vitamin D deficiency and low bone status in adult female garment factory workers in Bangladesh. *The British Journal of Nutrition* **2008**, 99, 1322–1329.
17. Islam, M.Z.; Karkkainen, M.; Lamberg-Al, C. Dietary calcium intake in young Bangladeshi female garment factory workers: associations with serum parathyroid hormone concentrations. *Asian Journal of Clinical Nutrition* **2013**, 5, 8–17.
18. Islam, M.Z.; Shamim, A.A.; Viljakainen, H.T.; Akhtaruzzaman, M.; Jehan, A.H.; Khan, H.U.; Al-Arif, F.A.; Lamberg-Allardt, C. Effect of vitamin D, calcium and multiple micronutrient supplementation on vitamin D and bone status in Bangladeshi premenopausal garment factory workers with hypovitaminosis D: a double-blinded, randomised, placebo-controlled 1-year intervention. *The British Journal of Nutrition* **2010**, 104, 241–247.
19. World Health Organization. *Iron Deficiency Anaemia. Assessment, Prevention, and Control*: *A Guide for Programme Managers*; World Health Organization: Geneva, Switzerland, **2001**.
20. World Health Organization. *Physical Status: The Use and Interpretation of Anthropometry*: *Report of a WHO Expert Committee*; World Health Organization: Geneva, Switzerland, **1995**.
21. Black, R.E.; Victora, C.G.; Walker, S.P.; Bhutta, Z.A.; Christian, P.; Onis, M. de; Ezzati, M.; Grantham-McGregor, S.; Katz, J.; Martorell, R.*; et al.* Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* **2013**, 382, 427–451.
22. BDLINK; HRINC. *Study on the Perceptions of Garment Factory Owners on Nutrition and the Feasibility for Pursuing Canteen Services in the Garment Sector in Cambodia*; International Labour Organization: Phnom Penh, Cambodia, **2012**.
23. Barba, C.V.; Cabrera, M.I. Recommended dietary allowances harmonization in Southeast Asia. *Asia Pacific Journal of Clinical Nutrition* **2008**, 17 (Suppl 2), 405–408.

2. Nutritional and micronutrient status of female workers in a garment factory in Cambodia (Paper I)

nutrients

MDPI

Article

Nutritional and Micronutrient Status of Female Workers in a Garment Factory in Cambodia

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Abstract: Background: Concerns about the nutritional status of Cambodian garment workers were raised years ago but data are still scarce. The objectives of this study are to examine the nutritional, hemoglobin and micronutrient status of female workers in a garment factory in Phnom Penh, Cambodia, and to assess if body mass index is associated with hemoglobin and/or micronutrient status. Methods: A cross-sectional survey was conducted among 223 female workers (nulliparous, non-pregnant) at a garment factory in Phnom Penh. Anthropometric measurements were performed and blood samples were taken to obtain results on hemoglobin, iron, vitamin A, vitamin B12 and inflammation status (hemoglobinopathies not determined). Bivariate correlations were used to assess associations. Results: Overall, 31.4% of workers were underweight, 26.9% showed anemia, 22.1% showed iron deficiency, while 46.5% had marginal iron stores. No evidence of vitamin A or vitamin B12 deficiency was found. Body mass index was associated with serum ferritin (negative) and serum retinol-binding protein (positive) concentrations, but not strongly. A comparison between underweight and not underweight workers resulted in distinctions for iron deficiency and iron deficiency anemia, with a higher prevalence among not underweight. Conclusions: The prevalence of underweight, anemia and poor iron status was high. Young and nulliparous female garment workers in Cambodia might constitute a group with elevated risk for nutritional deficiencies. Strategies need to be developed for improving their nutritional, micronutrient and health status. The poor iron status seems to contribute to the overall prevalence of anemia. Low hemoglobin and iron deficiency affected both underweight and those not underweight. Despite the fact that body mass index was negatively associated with iron stores, true differences in iron status between underweight and not underweight participants cannot be confirmed.

Keywords: underweight; anemia; micronutrient deficiency; garment factory; Cambodia; iron; vitamin A; vitamin B12; malnutrition; industry

1. Introduction

After a prolonged period of civil war, the first garment factories were set up in Cambodia in the early 1990s by foreign investments. Before that period the country did not develop any modern garment industry [1,2]. Investments were also mainly attracted by the steady supply of labor force at relatively low wage rates [1,2]. Until today, most factories belong to foreign investors and are located in and around the outskirts of Phnom Penh, the capital of Cambodia [1,2]. The majority of them

engage in "cut, make and trim" activities and depend on imported fabrics and machinery, as well as on technical and supervisory personnel from abroad [1,2]. In late 2015, there were in total about 700 factories in Cambodia, employing around 643,000 workers [3].

Some 86% of the garment and footwear workers are female, primarily young women from low-income rural households and many of them have a poor school education, which limits their options for working outside of agriculture and factory labor [4,5]. Additional finances made while working in the garment industry are often sent back to support family members, which has a substantial anti-poverty effect [5–7]. In 2015 the minimum wage for garment and footwear workers in Cambodia was 128 USD per month [3]. Beside the minimum salary, workers heavily rely on bonuses and overtime work [5,7]. Concerns about the nutritional status of Cambodian garment workers were raised years ago [6]. Malnutrition among workers has become a sensitive topic and has been linked to the mass faintings that are regularly reported from the factories [5]. Nevertheless, the action undertaken by stakeholders in the past was limited and data on the nutritional situation of garment workers are still scarce. It has been concluded that a decent diet, an adequate living standard and savings might be out of reach for this population [5–7]. The average daily amount spent by Cambodian garment workers on food (~1.5 USD) was regarded as not enough to ensure adequate dietary intake [5]. The expense on food is a result of extreme budgeting, achieved by the women through eating and living in groups and minimizing costs by bringing food from their hometowns [5–7]. Beyond that, thrift measures also involve workers skipping meals [5,6].

In addition to the nutritional status of female garment workers, the prevalence of anemia and micronutrient deficiencies is of importance in the Cambodian context [8]. According to the Cambodian Demographic Health Survey 2014 (CDHS 2014), 45% of women in reproductive age (15–49 years) were anemic [8]. Anemia of nutritional origin is caused by diets that lack sufficient amounts of essential hematopoietic nutrients, such as iron, vitamin A (VitA), vitamin B12 (VitB12) or folic acid, to meet the need for hemoglobin (Hb) and red blood cell synthesis [9,10]. Non-nutrition factors are especially menstrual blood loss, genetically determined hemoglobinopathies and parasite infestation, such as in malaria and helminths [9,11]. Malnutrition among women in reproductive age, with respect to underweight, anemia and micronutrient deficiencies, is associated with numerous poor health related outcomes, such as impaired cognition, reduced work capacity and impaired immune responses, leading to lowered resistance to infections [9,12,13]. During pregnancy, it is also associated with increased maternal morbidity and mortality, low birth weight, premature delivery and increased fetal and neonatal deaths [9,12,13].

All relevant actors along the Cambodian garment industry should be empowered to make informed choices through better information. However, despite an increasing number of nutrition-related research projects in Cambodia within the last years, there is still poor knowledge on the nutritional situation of female garment workers and just a few reports touched upon this topic [5,14]. The current paper is based on baseline data from the LUPROGAR study (Lunch Provision in Garment Factories), a factory-based randomized controlled trial, whose primary goal is to determine the impact of daily lunch provision through a canteen during workdays on the nutritional status (anthropometry and micronutrient status) among female garment workers in Cambodia. The two objectives of the present survey are to examine the nutritional, Hb and micronutrient status of female workers employed by a garment factory in Phnom Penh, Cambodia, and to assess if body mass index (BMI) is associated with Hb and/or micronutrient status among study subjects.

2. Materials and Methods

2.1. Study Site and Study Design

In this cross-sectional survey, baseline data from the LUPROGAR study were used. LUPROGAR was implemented at Apsara Garment Co. Ltd., Phnom Penh, Cambodia, an export-oriented garment factory located in the suburban commune Chom Chau in Cambodia's capital Phnom Penh, approximately 10 km west of the city center. Baseline data were collected in April 2015. The factory

was previously not operating a canteen, but a canteen was installed specifically for the LUPROGAR study. Enrolled study participants received either free lunch provision through the newly-established canteen during workdays (intervention arm) or an equal monetary compensation at the end of the study (control arm). At the time of study implementation, the factory employed about 1300 workers, the majority of which were young unmarried women from low-income rural households. Conditions of employment were assumed to be comparable with overall working conditions in the Cambodian garment sector. The factory operated on six workdays per week and was selected purposely, since the management was showing interest to collaborate in this research study.

2.2. Sample Size

The LUPROGAR study used an explorative approach (two tail) to estimate an appropriate sample size, as data on the nutritional and micronutrient status of Cambodian garment workers are rare, as well as data on the effects of lunch provision in this context. Calculations were carried out using G*Power software (Version 3.1.9.2, University of Kiel, Kiel, Germany). Assuming a 5% level of significance (alpha = 0.05) and a statistical power of 80% (beta = 0.20) to detect a small to medium standardized effect size of 0.35 (Cohen's d) between both arms using a two-sided test [15], 130 subjects in each group were required. To allow for about 20% loss to follow up, it was initially aimed at recruiting a total of 330 subjects, 165 subjects in each arm.

2.3. Enrolment of Study Participants

Firstly, the factory management, superintendents and union representatives were informed in detail about the objectives and procedure of the LUPROGAR study. Subsequently, the study was announced during a meeting to all factory employees. Written informed consents, including a study description in lay language, were obtained (signature or fingerprint) at lunch breaks and after end of work, prior to any data collection, by trained local project assistants. Workers who signed the informed consent were invited to the baseline assessment, which took place in a separate room during working hours and included a clinical screening performed by trained local nurses. Inclusion criteria for the LUPROGAR study were: female, nulliparous, non-pregnant and <31 years at date of enrolment. The exclusion criteria were: acute or chronic disease requiring treatment and/or medication, handicaps interfering with nutritional and/or health status, blood Hb < 7.0 g/dL, clinical signs of VitA or iodine deficiency and employment as supervisor/superintendent. Workers excluded from participation due to any health issues were referred for treatment.

2.4. Questionnaires

Trained local project assistants applied a semi-structured questionnaire, collecting data on background information and the socio-economic status of study participants and their respective households. Obtained data on age of workers was cross-checked with reference data from the factory's personnel department. Trained local project nurses administered a semi-structured health questionnaire, collecting data on present intake of medications, as well as on illness history and sick leave in the 14 days preceding the interview. Both questionnaires were similar to those from the CDHS 2014 [8] and were pre-tested under field conditions.

2.5. Anthropometric Measurements

Weight, height and mid-upper arm circumference (MUAC) of participants were assessed by two trained examiners following the guidelines from the Centers for Disease Control and Prevention (CDC) [16]. Weight was measured without shoes in light clothing to the nearest 0.1 kg, using an electronic SECA-UNICEF scale (UNISCALE, UNICEF supply). Height was measured to the nearest 0.1 cm, using a SECA 213 stadiometer (SECA, Hamburg, Germany). MUAC was measured to the nearest 0.1 cm, using a non-stretchable fiberglass measuring tape to determine the mid-point of the upper arm, and a MUAC measuring tape for adults supplied by UNICEF/WFP. All measurements

were taken twice and the mean was used for further analysis. The maximum tolerated differences were 0.5 kg for weight, 1.0 cm for height and 0.5 cm for MUAC, otherwise the measurement was repeated. BMI was calculated and subjects were classified using following cut-off points [16]: severe underweight (BMI < 16.0 kg/m^2), moderate underweight (BMI 16.0–16.99 kg/m^2), mild underweight (BMI 17.0–18.49 kg/m^2), normal weight (BMI 18.5–24.99 kg/m^2) and overweight (BMI 25.0–29.99 kg/m^2). All devices and measurement procedures were pre-tested under field conditions.

2.6. Blood Sample Collection and Analysis

Samples of 5 mL non-fasting venous blood (venepuncture at left or right arm) were taken by trained local nurses in a separate private area. Immediately after blood was collected, blood drops were put on a hydrophobic glass slide for subsequent twofold blood Hb measurement using a HemoCue Hb 301 photometer (HemoCue AB, Ängelholm, Sweden). Blood left in the syringe was filled into a serum vacutainer with clot activator (Becton Dickinson, Franklin Lakes, NJ, USA) and kept at room temperature for a minimum duration of 1 h to allow for blood clotting and afterwards kept chilled at 4 °C. Then it was separated within 3 h by centrifugation (2700 rpm, calculated equivalent at 1300× *g*, 10 min), aliquoted into capped Eppendorf tubes and again kept chilled at 4 °C. Samples were then transported in a cool box containing ice packs to the Department of Fisheries Post-Harvest Technologies and Quality Control (Phnom Penh, Cambodia) on a daily basis and kept frozen at −25 °C until further processing.

Subsamples for the determination of VitB12 concentration were transported in a cool box containing ice packs to the Pasteur Institute Cambodia (Phnom Penh, Cambodia). Serum VitB12 was measured by electrochemiluminescence (ECL), using a COBAS e 411 immunoassay analyser (Roche Diagnostics, Rotkreuz, Switzerland) with kits and control samples provided by the manufacturer. VitB12 deficiency was defined as serum VitB12 < 148 pmol/L and a marginal VitB12 deficiency as serum VitB12 ≥ 148 and < 222 pmol/L [17]. Remaining serum aliquots were shipped on dry ice to the Institute of Nutritional Sciences at the Justus Liebig University (Giessen, Germany) and stored at −25 °C until they were transported in a cool box containing ice packs to the VitMin laboratory (Willstaett, Germany) for determination of ferritin (FER), soluble transferrin receptor (sTfR), retinol-binding protein (RBP), C-reactive protein (CRP), and α1-acid-glycoprotein (AGP) concentrations. FER, RBP, sTfR, CRP, and AGP, were determined by a sandwich enzyme-linked immunosorbent assay (ELISA) technique [18], using pooled samples for quality control and certified samples (CDC, Atlanta, US and Bio-Rad, Hercules, CA, USA) to establish calibration curves for each indicator. All values represent the mean of an independent double measurement.

Subclinical inflammation was defined as increased CRP (>5 mg/L) and/or increased AGP concentrations (>1 g/L) and categorized into three stages: incubation (high CRP and normal AGP), early convalescence (both CRP and AGP elevated) and late convalescence (high AGP only) [19]. FER concentration was adjusted for inflammation by correction factors for each inflammation stage [19]. Iron deficiency was defined by depleted iron stores (adjusted serum FER < 15 µg/L) [9], tissue iron deficiency by high serum sTfR (>8.3 mg/L) [20] and marginal iron stores by adjusted serum FER ≥ 15 and < 50 µg/L [21]. Serum RBP concentrations were used as a surrogate measure for circulating retinol to evaluate VitA status [22]. RBP values were likewise adjusted for the presence of inflammation by correction factors for each stage of inflammation [23]. VitA deficiency was defined by adjusted serum RBP < 0.70 µmol/L and marginal VitA deficiency by adjusted serum RBP values ≥ 0.70 and < 1.05 µmol/L [22,24].

2.7. Data Management and Statistical Analysis

Data entry and validation by double entry of questionnaires and anthropometry sheets was performed by trained project assistants using EpiData software (Version 3.1, EpiData Association, Odense, Denmark). Data management and statistical analyses were executed using SPSS software (Version 22.0.0.1, IBM Corp., Armonk, NY, USA). Normality of distributions was evaluated using the Shapiro-Wilk test. As most continuous variables (background characteristics, anthropometry

and micronutrient status) were skewed, descriptive statistics for continuous variables are therefore represented by the median and interquartile range (IQR). Categorical variables are expressed as frequency and percentage. To assess if BMI is associated with Hb and micronutrient status, bivariate correlations between BMI and Hb, serum FER, serum sTfR, serum RBP and serum VitB12 concentrations were calculated with non-parametric Spearman's correlation. On the basis of illustration purposes, values for serum FER and serum sTfR were log-transformed in the correlation diagrams. The significance was set at 5% (p-value < 0.05).

2.8. Ethics

The LUPROGAR study was approved by the Institutional Review Board of the Faculty of Medicine at Justus Liebig University, Giessen, Germany (14 November 2014) and the National Ethics Committee for Health Research (NECHR) at the Ministry of Health, Phnom Penh, Cambodia (29 December 2014). Written informed consent was collected from all study participants prior to enrolment by signature or fingerprint. The ethics committees approved the consent format prior to data collection. The study was registered at the German Clinical Trials Register (9 January 2015, Identifier: DRKS00007666).

3. Results

3.1. Participant Characteristics

A total of 267 female workers signed the informed consent prior to enrolment, of whom 229 were present and 38 were not present (n = 30, ceased to work; n = 8, refused to participate) at the enrolment procedure. Another six workers were excluded from participation at the clinical screening (n = 2, blood Hb < 7.0 g/dL; n = 2, not nulliparous; n = 1, physical handicap, n = 1, chronic disease). Descriptive characteristics of the 223 enrolled study participants based on the questionnaire results are shown in Tables 1 and 2. Median age of participants was 20.9 years (IQR: 19.3–22.3 years). Median duration of employment in the factory was 10.7 months (IQR: 5.2–20.1 months). 66.4% (n = 148) reported a previous employment in another garment factory. Median monthly basic salary among workers was 128.0 USD (IQR: 128.0–133.0 USD), which increased by some 48% with bonus, overtime, and allowance, to a median value for last total monthly salary of 190.0 USD (IQR: 175.0–210.0). Almost all participants (99.6%, n = 222) stated regular monthly payments to their family households. The median for this substantial expense was 100.0 USD (IQR: 100.0–150.0 USD), which accounts for approximately 53% of median last total monthly salary.

Table 1. Descriptive characteristics (continuous variables) of female workers employed by a garment factory in Phnom Penh, Cambodia [1].

Characteristics	Median	IQR
General		
Age (years)	20.9	19.3–22.3
School attendance (years)	7.0	6.0–9.0
Duration of employment (months)	10.7	5.2–20.1
Income		
Monthly basic salary (USD)	128.0	128.0–133.0
Last monthly salary, incl. bonus, overtime, and allowance (USD) [2]	190.0	175.0–210.0
Expense		
Monthly payment to family household (USD) [3]	100.0	100.0–150.0
Household		
Number of people in household	5.0	4.0–6.0

[1] Total n = 223; [2] n = 215 (n = 8, newcomer (≤1 month of employment) without previous monthly salary); [3] n = 222 (n = 1, worker without monthly payment to family household); IQR: Interquartile range; USD: United States Dollar.

Table 2. Descriptive characteristics (categorical variables) of female workers employed by a garment factory in Phnom Penh, Cambodia [1].

Characteristics	*n*	%
Marital status		
Single	205	91.9
Married	14	6.3
Widowed/divorced	4	1.8
Religion		
Buddhist	223	100.0
Level of education		
Some primary	47	21.1
Completed primary (grade 6)	41	18.4
Some secondary	76	34.1
Completed secondary (grade 9)	41	18.4
Some high school	10	4.5
Completed high school (grade 12)	8	3.6
Hometown province		
Phnom Penh	11	4.9
Others	212	95.1
Accommodation on workdays		
Hometown, family household	68	30.5
Nearby place of friend/family	7	3.1
Nearby shared room for rent	146	65.5
Nearby private room for rent	2	0.9
Job type in factory		
Sewing	141	63.2
Quality control	36	16.1
Buttoning	15	6.7
Cutting	9	4.0
Packaging	9	4.0
Assistant	5	2.2
Others	8	3.6
Previous employment in other garment factory		
Yes	148	66.4
No	75	33.6
Households primary source of income		
Wage employment	131	58.7
Farming	53	23.8
Casual labor	17	7.6
Business/petty trade	13	5.8
Others	9	4.0

[1] Total $n = 223$.

The vast majority of participants were single (91.9%, $n = 205$). Overall, 39.9% ($n = 88$) did not complete more than a primary school education, with 21.1% ($n = 47$) of workers having left primary school without graduation. 26.5% ($n = 59$) completed secondary school or had a higher schooling. The hometown province of 95.1% ($n = 212$) of study participants was not Phnom Penh. Of the women, 30.5% ($n = 68$) were commuting, travelling between factory and family households in their hometown, while 69.5% ($n = 155$) reported a nearby accommodation on workdays. 65.5% ($n = 146$) stayed in a nearby shared room for rent. The main job types were sewing (63.2%, $n = 141$) and quality control (16.1%, $n = 36$). Their households' primary sources of income were primarily wage employment and farming with 58.7% ($n = 131$) and 23.8% ($n = 53$), respectively.

The prevalence of self-reported sicknesses and sick leave for a period of 14 days preceding the interview are shown in Table 3, with 45.7% (n = 102) of participants reporting a respiratory tract infection, 30.9% (n = 69) reporting fever and 20.2% (n = 45) reporting diarrhea. Overall, 61.4% (n = 137) reported any of these three sicknesses. In contrast to this, only 14.4% (n = 32) of workers took sick leave in the same period.

Table 3. Self-reported sickness and sick leave in the 14 days preceding the interview among female workers employed by a garment factory in Phnom Penh, Cambodia [1].

Variables	*n*	%
Self-reported sickness		
Respiratory tract infection	102	45.7
Fever	69	30.9
Diarrhea	45	20.2
Any of these sicknesses	137	61.4
Sick leave taken	32	14.4

[1] Total n = 223.

3.2. Nutritional Status

The results of the anthropometric assessments among participants are shown in Table 4. Median weight and height were 45.4 kg (IQR: 42.5–49.9 kg) and 153.5 cm (IQR: 150.0–156.9 cm), respectively. BMI values ranged from 14.7 kg/m^2 (severe underweight) to 27.8 kg/m^2 (overweight) and the median was 19.6 kg/m^2 (IQR: 18.3–21.2 kg/m^2). While 65.9% (n = 147) had a normal BMI (18.5–24.99 kg/m^2), 31.4% (n = 70) had a BMI lower than 18.5 kg/m^2, indicating underweight. Most of the underweight workers fell into the category of mild underweight (BMI 17.0–18.49 kg/m^2), in total 23.3% (n = 52) of all participants. The prevalence of moderate (BMI 16.0–16.99 kg/m^2) and severe underweight (BMI < 16.0 kg/m^2) was 5.8% (n = 13) and 2.2% (n = 5), respectively. Overweight (BMI 25.0–29.99 kg/m^2) was observed in only 2.7% (n = 6).

Table 4. Anthropometry and nutritional status of female workers employed by a garment factory in Phnom Penh, Cambodia [1].

Variables	Median or *n*	IQR or %	Min.	Max.
Anthropometry				
Weight (kg)	45.4	42.5–49.9	34.9	68.2
Height (cm)	153.5	150.0–156.9	142.5	166.6
MUAC (cm)	23.7	22.2–25.4	19.0	33.0
BMI (kg/m^2)	19.6	18.3–21.2	14.7	27.8
Nutritional status				
Underweight (BMI < 18.5 kg/m^2)	70	31.4		
Mild (BMI 17.0–18.49 kg/m^2)	52	23.3		
Moderate (BMI 16.0–16.99 kg/m^2)	13	5.8		
Severe (BMI < 16.0 kg/m^2)	5	2.2		
Normal (BMI 18.5–24.99 kg/m^2)	147	65.9		
Overweight (BMI 25.0–29.99 kg/m^2)	6	2.7		

[1] Total n = 223; IQR: Interquartile range; Min.: Minimum; Max.: Maximum; MUAC: Mid upper-arm circumference; BMI: Body mass index.

3.3. Hemoglobin and Micronutrient Status

Blood samples were available from 219 participants (n = 4, refused blood sampling). Results of the analyses are shown in Table 5. Median Hb was 12.5 g/dL (IQR: 11.9–13.2 g/dL). 26.9% (n = 59) of study participants had anemia (Hb < 12.0 g/dL), whereby most of anemic subjects showed a mild anemia

(Hb 11.0–11.9 g/dL). The adjusted median value of serum FER was 33.1 μg/L (IQR: 16.9–60.7 μg/L) and 22.1% (n = 48) of participants showed iron deficiency (adjusted FER < 15 μg/L), while 46.5% (n = 101) had marginal iron stores (adjusted FER ≥ 15 and <50 μg/L). The prevalence of tissue iron deficiency (sTfR > 8.3 mg/L) was lower with 10.1% (n = 22). Iron deficiency anemia (Hb < 12.0 g/dL and adjusted FER < 15 μg/L) was found in 12.9% (n = 28). Adjusted median serum RBP was 1.38 μmol/L (IQR: 1.21–1.58 μmol/L). None of the participants showed VitA deficiency (RBP < 0.70 μmol/L), while 7.4% (n = 16) showed marginal deficiency (RBP ≥ 0.70 and < 1.05 μmol/L). Median serum VitB12 concentration was 400 pmol/L (IQR: 299–513 pmol/L) and only one women showed VitB12 deficiency (VitB12 < 148 pmol/L), while 5.6% (n = 12) had a marginal VitB12 deficiency (VitB12 ≥ 148 and < 222 pmol/L).

Table 5. Hemoglobin, iron, vitamin A, vitamin B12 and subclinical inflammation status of female workers employed by a garment factory in Phnom Penh, Cambodia.

Variables	Median or n	IQR or %	Min.	Max.
Hemoglobin status [1]				
Hb (g/dL)	12.5	11.9–13.2	7.6	15.3
Anemia (Hb < 12.0 g/dL)	59	26.9		
Mild (Hb 11.0–11.9 g/dL)	42	19.2		
Moderate (Hb 8.0–10.9 g/dL)	16	7.3		
Severe (Hb < 8.0 g/dL)	1	0.5		
Iron status [2]				
Serum FER, unadjusted (μg/L)	34.5	17.6–62.4	3.8	217.8
Serum FER, adjusted [3] (μg/L)	33.1	16.9–60.7	3.8	217.8
Serum sTfR (mg/L)	5.4	4.4–6.5	2.7	31.2
Deficiency (adjusted [3] serum FER < 15 μg/L)	48	22.1		
Marginal stores (adjusted [3] serum FER ≥ 15 and < 50 μg/L)	101	46.5		
Tissue iron deficiency (serum sTfR > 8.3 mg/L)	22	10.1		
Iron deficiency anemia [2]				
Hb < 12.0 g/dL and adjusted [3] serum FER < 15 μg/L	28	12.9		
Vitamin A status [2]				
Serum RBP, unadjusted (μmol/L)	1.37	1.21–1.57	0.70	2.33
Serum RBP, adjusted [3] (μmol/L)	1.38	1.21–1.58	0.78	2.33
Deficiency (adjusted [3] serum RBP < 0.70 μmol/L)	0	0.0		
Marginal deficiency (adjusted [3] serum RBP ≥0.70 and < 1.05 μmol/L)	16	7.4		
Vitamin B12 status [4]				
Serum VitB12 (pmol/L)	400	299–513	107	1206
Deficiency (serum VitB12 < 148 pmol/L)	1	0.5		
Marginal deficiency (serum VitB12 ≥ 148 and < 222 pmol/L)	12	5.6		
Subclinical inflammation [2]				
CRP (mg/L)	0.23	0.13–0.48	0.02	43.55
AGP (g/L)	0.58	0.48–0.72	0.26	2.50
Incubation (CRP > 5 mg/L only)	2	0.9		
Early convalescence (AGP > 1 g/L and CRP > 5 mg/L)	4	1.8		
Late convalescence (AGP > 1 g/L only)	14	6.5		

[1] Total n = 219; [2] Total n = 217 (n = 2, no aliquot); [3] Values adjusted for inflammation as described in methods section; [4] Total n = 216 (n = 3, no aliquot); IQR: Interquartile range; Min.: Minimum; Max.: Maximum; Hb: Hemoglobin; FER: Ferritin; sTfR: Soluble transferrin receptor; RBP: Retinol binding protein; CRP: C-reactive protein; AGP: α1-acid-glycoprotein.

Bivariate correlations between BMI and blood Hb concentration, and between BMI and biochemical parameters of micronutrient status are shown in Figure 1. BMI showed only small-sized correlations with Hb, serum FER, serum sTfR and serum RBP concentrations. BMI was negatively correlated with serum FER (rho = −0.144, p = 0.034, BCa 95% CI = −0.271, −0.015) and positively correlated with serum RBP (rho = 0.180, p = 0.008, BCa 95% CI = 0.050, 0.305). However, the relationships between BMI and Hb (rho = −0.125, p = 0.066, BCa 95% CI = −0.255, 0.016) and

between BMI and serum sTFR (rho = 0.126, p = 0.064, BCa 95% CI = −0.020, 0.259) were not significant. No relationship between BMI and serum VitB12 was found (rho = −0.027; p = 0.697, BCa 95% CI = −0.164, 0.110).

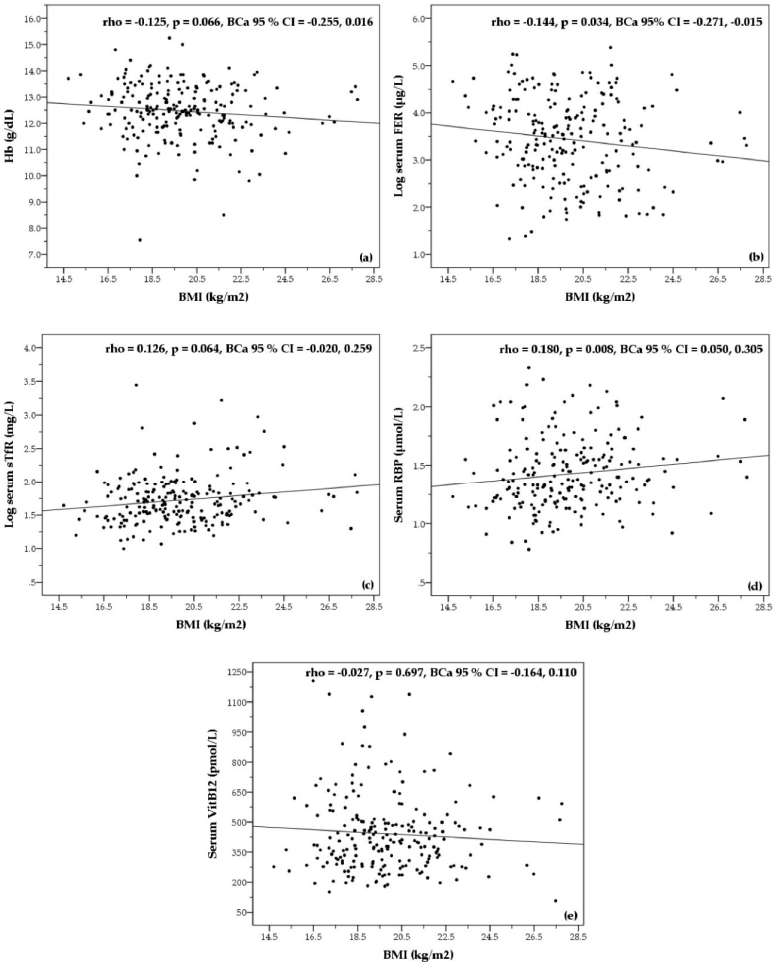

Figure 1. Bivariate correlations between BMI and Hb (**a**); serum FER (**b**); serum sTfR (**c**); serum RBP (**d**); serum VitB12 (**e**) concentrations of female workers employed by a garment factory in Phnom Penh, Cambodia. Correlation coefficients (rho), calculated with non-parametric Spearman's correlation, include bias corrected and accelerated bootstrap 95% confidence intervals (BCa 95% CI). For illustration purposes, values for serum FER and serum sTfR were log-transformed in the diagrams. Hb: Hemoglobin; FER: Ferritin; sTfR: Soluble transferrin receptor; RBP: Retinol binding protein; VitB12: Vitamin B12; BMI: Body mass index.

Prevalence of anemia, micronutrient deficiencies and subclinical inflammation for underweight (BMI < 18.5 kg/m^2) and not underweight participants (BMI ≥ 18.5 kg/m^2) are shown in Table 6. Distinctions were observed for iron deficiency (adjusted FER < 15 µg/L) and iron deficiency anemia (Hb < 12.0 g/dL and adjusted FER < 15 µg/L), with higher prevalence among not underweight workers. 5.9% (n = 4) of underweight workers showed iron deficiency anemia, while the prevalence among not underweight workers was 16.1% (n = 24). The prevalence of iron deficiency among workers with a BMI ≥ 18.5 kg/m^2 was 26.2% (n = 39), compared to underweight workers with 13.2% (n = 9). No relevant differences between groups were found for anemia (Hb < 12.0 g/dL), marginal iron stores (adjusted FER ≥ 15 and < 50 µg/L), tissue iron deficiency (sTfR > 8.3 mg/L), VitA deficiencies (RBP < 0.70 µmol/L and RBP ≥ 0.70 and < 1.05 µmol/L), VitB12 deficiencies (VitB12 < 148 pmol/L and VitB12 ≥ 148 and < 222 pmol/L) and subclinical inflammation (CRP > 5.0 mg/L and/or AGP > 1.0 g/L).

Table 6. Anemia, micronutrient deficiencies and subclinical inflammation by underweight and not underweight female workers employed by a garment factory in Phnom Penh, Cambodia.

Variables	BMI < 18.5 (kg/m^2)		BMI ≥ 18.5 (kg/m^2)	
	n	%	*n*	%
Anemia [1]				
Hb < 12.0 g/dL	17	24.6	42	28.0
Iron deficiency anaemia [2]				
Hb < 12.0 g/dL and adjusted [3] serum FER < 15 µg/L	4	5.9	24	16.1
Iron [2]				
Deficiency (adjusted [3] serum FER < 15 µg/L)	9	13.2	39	26.2
Marginal stores (adjusted [3] serum FER ≥ 15 and < 50 µg/L)	32	47.1	69	46.3
Tissue iron deficiency (serum sTfR > 8.3 mg/L)	6	8.8	16	10.7
Vitamin A [2]				
Deficiency (adjusted [3] serum RBP < 0.70 µmol/L)	0	0.0	0	0.0
Marginal deficiency (adjusted [3] serum RBP ≥ 0.70 and < 1.05 µmol/L)	7	10.3	9	6.0
Vitamin B12 [4]				
Deficiency (serum VitB12 < 148 pmol/L)	0	0.0	1	0.7
Marginal deficiency (serum VitB12 ≥ 148 and < 222 pmol/L)	5	7.5	7	4.7
Subclinical inflammation [2]				
Any inflammation phase (CRP > 5.0 mg/L and/or AGP > 1.0 g/L)	4	5.9	16	10.7

[1] Total n = 219 (n = 69, BMI < 18.5 kg/m^2; n = 150, BMI ≥ 18.5 kg/m^2); [2] Total n = 217 (n = 68, BMI < 18.5 kg/m^2; n = 149, BMI ≥ 18.5 kg/m^2); n = 2, no aliquot; [3] Values adjusted for inflammation as described in methods section; [4] Total n = 216 (n = 67, BMI < 18.5 kg/m^2; n = 149, BMI ≥ 18.5 kg/m^2); n = 3, no aliquot; BMI: Body mass index; Hb: Hemoglobin; FER: Ferritin; sTfR: Soluble transferrin receptor; RBP: Retinol binding protein; VitB12: Vitamin B12; CRP: C-reactive protein; AGP: α1-acid-glycoprotein.

4. Discussion

In this paper, it is shown that the nutritional status of female garment workers in Cambodia might be of concern, with underweight (BMI < 18.5 kg/m^2), anemia (Hb < 12.0 g/dL) and iron deficiency (serum FER < 15 µg/L) being prevalent among study participants.

Underweight was found in approximately one-third (31.4%) of the women. Although most underweight workers showed mild underweight (BMI 17.0–18.49 kg/m^2), the term "mild" in this classification should not veil the various serious consequences of it [12,13]. According to the World Health Organization (WHO), a prevalence of 20%–39% underweight in a given population is considered a critical situation [12]. A similar prevalence of underweight (36%) among female garment workers in Cambodia has been reported by NGOs in 2013, based on a small cross-sectional survey [5]. On the contrary, a recent International Labour Organization (ILO) study conducted in several Cambodian factories found a distinctly lower prevalence of 14.3% underweight among female workers, who were

mainly married, not nulliparous and whose age was therefore higher [14]. The subjects enrolled in this study were relatively young, nulliparous (inclusion criteria) and mainly single. They might constitute a group of workers who is especially at risk for underweight, with a prevalence rate that is considerably higher than the national estimate for underweight of women of reproductive age (15–49 years) in Cambodia (which is 14.0%) [8]. Many young workers will likely start their employment when they are already underweight, as shown for adolescent female garment workers in Bangladesh [25]. Underweight among Cambodian women is especially widespread among young women aged 15–19 years (27.5%) [8].

It is presumed that expenses on food, and hence dietary intake in terms of quantity and quality, might be compromised by the limited financial means of study participants. Disposable income of workers is mainly determined by remittances, i.e., regular monthly payments to their family households. These financial commitments were the largest expense among workers in this study (on average 53% of total monthly salary). Expenses on food among Cambodian garment workers increased within the last years, as consumer prices did as well, but have been continuously described as low and insufficient to ensure an adequate dietary intake [5,7]. However, reliable data on the actual dietary intake among Cambodian garment workers are missing and further research with respect to this aspect should be undertaken.

Infectious diseases are known to have negative effects on nutritional status, and vice versa; a poor nutritional status interferes with immune functions and thereby enhances the risk for infections [26]. Study participants frequently reported symptoms of respiratory tract infections (45.7%), fever (30.9%) and diarrhea (20.2%) in the 14 days preceding the interview, with 61.4% who reported at least one of these. However, no differences in the prevalence of sicknesses and sick leave among underweight and not underweight study participants were observed (data not shown). In addition, only 14.4% of subjects stated that they have taken sick leave in the same period, leading to the conclusion that many workers tend to continue work despite being sick.

Anemia affected approximately one out of four subjects (26.9%). According to the WHO, anemia is a public health problem when the prevalence is >20% [9]. The prevalence of anemia among participants was expected to be higher, since the CDHS 2014 found that 45% of Cambodian women of reproductive age were anemic [8]. The same high prevalence among female garment workers was reported by the recent ILO survey [14]. Similar to the data presented here, rates of 30% anemia among non-pregnant Cambodian women have been reported [27]. Currently, the contributors to the high prevalence of anemia in Cambodia are still not fully understood [28]. In the past, iron deficiency was regarded as the most important factor, however, recent studies have shown a low prevalence of iron deficiency and concluded a low impact on hemoglobin concentrations among Cambodian women [24,28]. Genetic hemoglobin disorders lead to lower hemoglobin concentrations and an increased risk of anemia [27]. According to the literature, these inherited hemoglobinopathies affect >50% of the Cambodian population, the most common include hemoglobin E variants and α-thalassemia, resulting in reduced or abnormal hemoglobin synthesis [27,29,30]. Although the prevalence of hemoglobinopathies was not determined in the study population, it is likely that these disorders contribute to the prevalence of anemia. Recently, it was questioned if increasing the provision of iron will improve anemia in the Cambodian setting [28]. Measures to reduce zinc and folic acid deficiency, as well as to treat and prevent hookworm infections, were suggested to be included in current interventions [28].

In the current study, approximately one-fifth (22.1%) of the participants were iron deficient and approximately one-half (46.5%) of the women showed marginal iron store values and will be especially at risk to become iron deficient if pregnancy occurs [21]. These figures are higher compared to representative prevalence rates for Cambodian women (iron deficiency <10%; marginal iron stores ~40%) [24,28]. In addition, 10.1% showed tissue iron deficiency. The prevalence of iron deficiency anemia (simultaneous low Hb and iron deficiency) among women in the present study was 12.9%. Considering this, poor iron status partially explains the prevalence of anemia in this population.

Animal source foods are a primary source for dietary iron intake [31]. However, in Cambodia they belong to the most expensive food products [32]. Even though recent findings suggest that iron-rich foods (e.g., flesh meat, fish) are daily consumed by a majority of female garment workers [14], the quantities might be too small to meet dietary reference intakes (DRI). Data supporting this assumption were reported for Cambodian women in a rural area [32].

No evidence of VitA (0.0%) or VitB12 deficiency (0.5%) was found among subjects and the prevalence of marginal deficiencies for both were <10% (7.4% marginal VitA deficiency; 5.6% marginal VitB12 deficiency), which is in line with national representative data [24,28]. It is concluded, that the VitA and the VitB12 status of participants is not of concern and is not likely contributing significantly to the anemia burden in the studied women [9].

The secondary objective of this study was to examine associations between BMI and hemoglobin as well as micronutrient status among the participating women. In a simple bivariate correlation analysis, BMI showed only small-sized associations with serum FER and RBP. Small-sized effects between BMI and Hb, and BMI with serum sTfR were not significant and no association between BMI and serum VitB12 concentration was observed.

Opposite to the expectations, BMI was negatively associated with serum FER (rho = −0.144, $p = 0.034$, BCa 95% CI = −0.271, −0.015). A comparison between underweight and not underweight workers resulted in distinctions for iron deficiency and iron deficiency anemia, with a 2–2.5 times higher prevalence among participants with a BMI > 18.5 kg/m^2. Still, it is to be noted that the relationship between BMI and serum FER was only marginally significant and that the number of cases with iron deficiency and iron deficiency anemia within both groups were relatively small. Therefore, true differences in iron status between underweight and not underweight participants cannot be confirmed. Amenorrhea (absence of menstruation) is known to be linked with underweight [33] and, although no information on menstrual blood loss was obtained in this study, could be considered regarding a slightly better iron status in underweight workers. But, the inverse relationship between BMI and iron status has been consistently reported by others, especially in overweight/obese compared to normal weight individuals [34]. On the contrary, a cross-sectional study among 1530 Vietnamese women of reproductive age reported positive associations between BMI with Hb and plasma FER, although this was not associated with a different prevalence of anemia or iron deficiency among different BMI groups [35].

BMI was positively associated with serum RBP (rho = 0.180, $p = 0.008$, BCa 95% CI = 0.050, 0.305), but this weak relationship did not result in a distinctly different prevalence of marginal VitA deficiency between underweight and not underweight subjects. Low plasma retinol concentrations and a higher prevalence of marginal VitA status among underweight women were reported from the mentioned study in Vietnam [35]. The authors showed that food energy intake among participants increased along the BMI classifications and concluded that higher micronutrient intakes could have resulted in a better VitA status of individuals with a BMI > 18.5 kg/m^2. No data on energy or micronutrient intake among participants were collected in the present study, however, this conclusion could be also valid for the study population. Moreover, the uptake of VitA and carotenoids is linked to dietary fat intake [36], which in turn is positively associated with BMI.

Limitations of the Study

A main limitation of the present study was the monocentric cross-sectional design, in which findings cannot be derived beyond the locality and population included in this survey. Study participants could not get randomly selected and this survey was conducted with a relatively small number of women. However, it is assumed that this does not restrict the interpretation of the results obtained, since inclusion criteria represented the majority of garment workers employed by the factory. Initially, it was planned to enroll 330 participants for the LUPROGAR study. Fear and reservations related to the blood sampling procedure were reported by many workers, especially due to headlines

about a HIV outbreak caused by unlicensed clinicians reusing syringes shortly before the baseline assessment [37].

The prevalence of hemoglobinopathies was not measured, although this is likely to be a contributing factor to the observed prevalence of anemia. Furthermore, menstrual blood loss, a determinant of iron stores in women of reproductive age [38], was not recorded. Inherited hemoglobin disorders are also known to impact on iron markers [27,39]. Recently, these effects were examined in a cross-sectional survey among 450 Cambodian women [39]. In this study, only the Hb EE genotype (found in ~7% of subjects) was significantly associated with a 50% higher geometric mean ferritin concentration, compared to those with normal Hb AA genotype. The prevalence of iron deficiency (ferritin < 15 μg/L) did not differ between subjects with any abnormal Hb genotype and subjects with Hb AA. Regarding sTfR values, the authors reported that Hb EE and Hb Constant Spring genotypes (the later affecting ~4% of subjects) were significantly associated with a 51% and 44% increase in geometric mean sTfR concentration, respectively. Consequently, the prevalence of tissue iron deficiency (sTfR > 8.3 mg/L) among women with any hemoglobinopathy was significantly higher than among women with normal Hb AA (~26% vs. ~10%). The prevalence of elevated sTfR was especially high (55%) among Hb EE subjects. Based on their findings, the authors conclude that ferritin values, in contrast to sTfR, appear to reflect more accurately iron deficiency in Cambodian women [39]. In the current study, main statements regarding the iron status of participants are based on the ferritin data, which remain informative, although ferritin values might not represent true iron status among a subgroup with Hb EE disorder. sTfR concentration as an indicator of iron status seems to be less reliable in the Cambodian context [39].

Moreover, RBP is a proxy indicator for retinol concentrations and although the correlation between retinol and RBP is high, as retinol is bound to RBP in a 1:1 ratio, RBP concentrations tend to underestimate VitA deficiency due to the presence of holo-RBP (RBP without retinol) in the circulation, which is especially the case at lower retinol concentrations [40]. However, as the prevalence of RBP < 1.05 μmol/L is also low (<10%), it is assumed that our finding on frank VitA deficiency in this population is valid.

5. Conclusions

The prevalence of underweight, anemia and poor iron status among study participants is of concern. According to the present study, approximately two-thirds of subjects (iron deficient or with marginal iron stores) will have a high risk for iron deficiency when they get pregnant. Young and nulliparous garment workers in Cambodia are identified as a part of the workforce with a high risk for undernutrition and an elevated risk for nutritional deficiencies. Therefore, strategies need to be developed for improving their nutritional, micronutrient and health status. In addition, adequate national actions to tackle malnutrition among female adolescents should be undertaken. Despite a recent rise in minimum salaries, as seen for the Cambodian garment industry within the last years, higher salaries might not automatically lead to improved nutrition among workers in the short term, as they primarily fulfil a major contribution to the social securing of their family households. Consequently, improving national social and health security systems, especially for low-income rural households, might be one pathway that could directly lead to increased disposable incomes and indirectly lead to improved nutrition among garment workers.

In contrast to recent nationwide results among women of reproductive age, the poor iron status in the study population seems to contribute to the overall prevalence of anemia. However, the VitA and VitB12 status of participants is not of concern. Low hemoglobin and iron deficiency affected both groups, those underweight as well as those normal and overweight, unexpectedly with a higher prevalence among participants with a BMI > 18.5 kg/m^2. Despite the fact that BMI was negatively associated with iron stores, true differences in iron status between underweight and not underweight participants cannot be confirmed. As reported in other studies, it should be noted

that hemoglobinopathies (not determined in this study) are likely to impact on Hb concentration (decreased Hb) and markers of iron status (partly increased values of FER and sTFR).

The overall findings should have practical implications for the design and implementation of programs and strategies aiming at the improvement of the nutritional and micronutrient status among young female garment workers in Cambodia.

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Abbreviations

The following abbreviations are used in this manuscript:

USD	United States Dollar
CDHS	Cambodia Demographic Health Survey
VitA	Vitamin A
VitB12	Vitamin B12
Hb	Hemoglobin
LUPROGAR	Lunch Provision in Garment Factories
BMI	Body mass index
UNICEF	United Nations Children's Emergency Fund
MUAC	Mid upper-arm circumference
FER	Ferritin
sTfR	Soluble transferrin receptor
RBP	Retinol binding protein
CRP	C-reactive protein
AGP	α1-acid-glycoprotein
IQR	Interquartile range
Min.	Minimum
Max.	Maximum
WHO	World Health Organization
NGO	Non-government organization
ILO	International Labour Organization
HIV	Human immunodeficiency virus

References

1. Asuyama, Y.; Neou, S. How has the Cambodian garment industry evolved? In *Dynamics of the Garment Industry in Low-Income Countries: Experience of Asia and Africa*; Fukunishi, T., Ed.; Japan External Trade Organization: Chiba, Japan, 2012; Chapter 3.
2. Bargawi, O. *Cambodia's Garment Industry—Origins and Future Prospects*; Overseas Development Institute: London, UK, 2005.
3. International Labour Organization. *Cambodian Garment and Footwear Sector Bulletin. Issue 3. How Is Cambodia's Minimum Wage Adjusted;* International Labour Organization: Phnom Penh, Cambodia, 2016.
4. International Labour Organization. *Cambodian Garment and Footwear Sector Bulletin. Issue 2. Solid First Half of 2015 for Cambodia's Garment and Footwear Sector*; International Labour Organization: Phnom Penh, Cambodia, 2015.

5. McMullen, A. *Shop'til They Drop. Fainting and Malnutrition in Garment Workers in Cambodia*; Labour behind the Label; Community Legal Education Centre: Phnom Penh, Cambodia, 2013. Available online: https://www.cleanclothes.org/resources/national-cccs/shop-til-they-drop (accessed on 28 January 2016).
6. International Labour Organization; World Bank. *Cambodia. Women and Work in the Garment Industry*; International Labour Organization: Phnom Penh, Cambodia, 2006.
7. Kang, C.; Liv, D. *Living Wage Survey for Cambodia's Garment Industry*; Cambodia Institute of Development Study: Phnom Penh, Cambodia, 2009. Available online: http://www.fes.or.id/fes/download/Survey_Result_Cambodia.pdf (accessed on 18 May 2016).
8. National Institute of Statistics; Directorate General for Health; ICF International. *Cambodia Demographic and Health Survey 2014*; National Institute of Statistics; Directorate General for Health; ICF International: Phnom Penh, Cambodia and Rockville, MD, USA, 2015.
9. World Health Organization. *Iron Deficiency Anaemia. Assessment, Prevention, and Control: A Guide for Programme Managers*; World Health Organization: Geneva, Switzerland, 2001.
10. Koury, M.J.; Ponka, P. New insights into erythropoiesis: The roles of folate, vitamin B12, and iron. *Annu. Rev. Nutr.* **2004**, *24*, 105–131. [CrossRef] [PubMed]
11. Charles, C.V.; Summerlee, A.J.; Dewey, C.E. Anemia in Cambodia: Prevalence, etiology and research needs. *Asia Pac. J. Clin. Nutr.* **2012**, *21*, 171–181. [PubMed]
12. World Health Organization. *Physical Status: The Use and Interpretation of Anthropometry*; World Health Organization: Geneva, Switzerland, 1995.
13. Black, R.E.; Victora, C.G.; Walker, S.P.; Bhutta, Z.A.; Christian, P.; de Onis, M.; Ezzati, M.; Grantham-McGregor, S.; Katz, J.; Martorell, R.; et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* **2013**, *382*, 427–451. [CrossRef]
14. International Labour Organization. *Garment Workers' Health and Nutrition Status, and Food Provision in Factories. A Study from Selected Enterprises in Cambodia*; International Labour Organization: Phnom Penh, Cambodia, 2016.
15. Cohen, J. A power primer. *Psychol. Bull.* **1992**, *112*, 155–159. [CrossRef] [PubMed]
16. Centers for Disease Control and Prevention. *National Health and Nutrition Examination Survey (NHANES). Anthropometry Procedures Manual*; Centers for Disease Control and Prevention: Atlanta, GA, USA, 2007.
17. Allen, L.H. How common is vitamin B-12 deficiency? *Am. J. Clin. Nutr.* **2009**, *89*, 693S–696S. [CrossRef] [PubMed]
18. Erhardt, J.G.; Estes, J.E.; Pfeiffer, C.M.; Biesalski, H.K.; Craft, N.E. Combined measurement of ferritin, soluble transferrin receptor, retinol binding protein, and C-reactive protein by an inexpensive, sensitive, and simple sandwich enzyme-linked immunosorbent assay technique. *J. Nutr.* **2004**, *134*, 3127–3132. [PubMed]
19. Thurnham, D.I.; McCabe, L.D.; Haldar, S.; Wieringa, F.T.; Northrop-Clewes, C.A.; McCabe, G.P. Adjusting plasma ferritin concentrations to remove the effects of subclinical inflammation in the assessment of iron deficiency: A meta-analysis. *Am. J. Clin. Nutr.* **2010**, *92*, 546–555. [CrossRef] [PubMed]
20. Thurnham, D.I.; Northrop-Clewes, C.A.; Knowles, J. The use of adjustment factors to address the impact of inflammation on vitamin A and iron status in humans. *J. Nutr.* **2015**, *145*, 1137S–1143S. [CrossRef] [PubMed]
21. Milman, N. Iron in pregnancy: How do we secure an appropriate iron status in the mother and child? *Ann. Nutr. Metab.* **2011**, *59*, 50–54. [CrossRef] [PubMed]
22. Gamble, M.V.; Ramakrishnan, R.; Palafox, N.A.; Briand, K.; Berglund, L.; Blaner, W.S. Retinol binding protein as a surrogate measure for serum retinol: Studies in vitamin A-deficient children from the Republic of the Marshall Islands. *Am. J. Clin. Nutr.* **2001**, *73*, 594–601. [PubMed]
23. Thurnham, D.I.; McCabe, G.P.; Northrop-Clewes, C.A.; Nestel, P. Effects of subclinical infection on plasma retinol concentrations and assessment of prevalence of vitamin A deficiency: Meta-analysis. *Lancet* **2003**, *362*, 2052–2058. [CrossRef]
24. Wieringa, F.T.; Sophonneary, P.; Whitney, S.; Mao, B.; Berger, J.; Conkle, J.; Dijkhuizen, M.A.; Laillou, A. Low prevalence of iron and vitamin A deficiency among Cambodian women of reproductive age. *Nutrients* **2016**, *8*, 197. [CrossRef] [PubMed]
25. Khan, M.R.; Ahmed, F. Physical status, nutrient intake and dietary pattern of adolescent female factory workers in urban Bangladesh. *Asia Pac. J. Clin. Nutr.* **2005**, *14*, 19–26. [PubMed]
26. Krawinkel, M.B. Interaction of nutrition and infections globally: An overview. *Ann. Nutr. Metab.* **2012**, *61*, 39–45. [CrossRef] [PubMed]

27. Karakochuk, C.D.; Whitfield, K.C.; Barr, S.I.; Lamers, Y.; Devlin, A.M.; Vercauteren, S.M.; Kroeun, H.; Talukder, A.; McLean, J.; Green, T.J. Genetic hemoglobin disorders rather than iron deficiency are a major predictor of hemoglobin concentration in women of reproductive age in rural Prey Veng, Cambodia. *J. Nutr.* **2015**, *145*, 134–142. [CrossRef] [PubMed]
28. Wieringa, F.; Dahl, M.; Chamnan, C.; Poirot, E.; Kuong, K.; Sophonneary, P.; Sinuon, M.; Greuffeille, V.; Hong, R.; Berger, J.; et al. The high prevalence of anemia in Cambodian children and women cannot be satisfactorily explained by nutritional deficiencies or hemoglobin disorders. *Nutrients* **2016**, *8*, 348. [CrossRef] [PubMed]
29. Carnley, B.P.; Prior, J.F.; Gilbert, A.; Lim, E.; Devenish, R.; Sing, H.; Sarin, E.; Guhadasan, R.; Sullivan, S.G.; Wise, C.A.; et al. The prevalence and molecular basis of hemoglobinopathies in Cambodia. *Hemoglobin* **2006**, *30*, 463–470. [CrossRef] [PubMed]
30. Weatherall, D.J.; Clegg, J.B. Inherited haemoglobin disorders: An increasing global health problem. *Bull. World Health Organ.* **2001**, *79*, 704–712. [PubMed]
31. Kongkachuichai, R.; Napatthalung, P.; Charoensiri, R. Heme and nonheme iron content of animal products commonly consumed in Thailand. *J. Food Compos. Anal.* **2002**, *15*, 389–398. [CrossRef]
32. Wallace, L.J.; Summerlee, A.J.; Dewey, C.E.; Hak, C.; Hall, A.; Charles, C.V. Women's nutrient intakes and food-related knowledge in rural Kandal province, Cambodia. *Asia Pac. J. Clin. Nutr.* **2014**, *23*, 263–271. [PubMed]
33. Mitan, L.A.P. Menstrual dysfunction in anorexia nervosa. *J. Pediatr. Adolesc. Gynecol.* **2004**, *17*, 81–85. [CrossRef] [PubMed]
34. Cepeda-Lopez, A.C.; Aeberli, I.; Zimmermann, M.B. Does obesity increase risk for iron deficiency? A review of the literature and the potential mechanisms. *Int. J. Vitam. Nutr. Res.* **2010**, *80*, 263–270. [CrossRef] [PubMed]
35. Laillou, A.; Yakes, E.; Le, T.H.; Wieringa, F.T.; Le, B.M.; Moench-Pfanner, R.; Berger, J. Intra-individual double burden of overweight and micronutrient deficiencies among Vietnamese women. *PLoS ONE* **2014**, *9*, e110499. [CrossRef] [PubMed]
36. McLaren, D.S.; Kraemer, K. Vitamin A in health. *World Rev. Nutr. Diet.* **2012**, *103*, 33–51. [PubMed]
37. Seangly, P.; Cuddy, A. Doctor gets 25 years for HIV outbreak. *The Phnom Penh Post*, 4 December 2015.
38. Harvey, L.J.; Armah, C.N.; Dainty, J.R.; Foxall, R.J.; John Lewis, D.; Langford, N.J.; Fairweather-Tait, S.J. Impact of menstrual blood loss and diet on iron deficiency among women in the UK. *Br. J. Nutr.* **2005**, *94*, 557–564. [CrossRef] [PubMed]
39. Karakochuk, C.D.; Whitfield, K.C.; Rappaport, A.I.; Barr, S.I.; Vercauteren, S.M.; McLean, J.; Prak, S.; Hou, K.; Talukder, A.; Devenish, R.; et al. The homozygous hemoglobin EE genotype and chronic inflammation are associated with high serum ferritin and soluble transferrin receptor concentrations among women in rural Cambodia. *J. Nutr.* **2015**, *145*, 2765–2773. [CrossRef] [PubMed]
40. Dijkhuizen, M.A.; Wieringa, F.T.; West, C.E.; Muherdiyantiningsih; Muhilal. Concurrent micronutrient deficiencies in lactating mothers and their infants in Indonesia. *Am. J. Clin. Nutr.* **2001**, *73*, 786–791. [PubMed]

3. Estimated nutritive value of low-price model lunch sets provided to garment workers in Cambodia (Paper II)

nutrients

MDPI

Article

Estimated Nutritive Value of Low-Price Model Lunch Sets Provided to Garment Workers in Cambodia

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Abstract: Background: The establishment of staff canteens is expected to improve the nutritional situation of Cambodian garment workers. The objective of this study is to assess the nutritive value of low-price model lunch sets provided at a garment factory in Phnom Penh, Cambodia. Methods: Exemplary lunch sets were served to female workers through a temporary canteen at a garment factory in Phnom Penh. Dish samples were collected repeatedly to examine mean serving sizes of individual ingredients. Food composition tables and NutriSurvey software were used to assess mean amounts and contributions to recommended dietary allowances (RDAs) or adequate intake of energy, macronutrients, dietary fiber, vitamin C (VitC), iron, vitamin A (VitA), folate and vitamin B12 (VitB12). Results: On average, lunch sets provided roughly one third of RDA or adequate intake of energy, carbohydrates, fat and dietary fiber. Contribution to RDA of protein was high (46% RDA). The sets contained a high mean share of VitC (159% RDA), VitA (66% RDA), and folate (44% RDA), but were low in VitB12 (29% RDA) and iron (20% RDA). Conclusions: Overall, lunches satisfied recommendations of caloric content and macronutrient composition. Sets on average contained a beneficial amount of VitC, VitA and folate. Adjustments are needed for a higher iron content. Alternative iron-rich foods are expected to be better suited, compared to increasing portions of costly meat/fish components. Lunch provision at Cambodian garment factories holds the potential to improve food security of workers, approximately at costs of <1 USD/person/day at large scale. Data on quantitative total dietary intake as well as physical activity among workers are needed to further optimize the concept of staff canteens.

Keywords: nutritive value; recommended dietary allowance; lunch provision; Cambodia; garment factory; staff canteen; underweight; anemia; micronutrient deficiency; malnutrition

1. Introduction

Cambodia's export-oriented garment industry has grown steadily over the past two decades, representing the mainstay of the country's economy and accounting for 80% of total merchandise exports [1–3]. By midyear 2016, about 600 registered garment factories were operating in Cambodia, employing 610,000 workers [1]. Most factories manage low-value-added activities ("cut, make and trim") and depend on imported fabrics and machinery, as well as on technical and supervisory personnel from abroad [2,3]. Factories are usually owned by foreign investors and are located in and around the suburbs of Phnom Penh, the capital of Cambodia [2,3]. The vast majority of garment

workers are female (87%), mostly young women who migrate from low-income rural households [1,4]. Many have a poor school education, limiting their work options to agriculture and factory labor [4,5]. In 2016, the minimum wage for garment workers in Cambodia was set to 140 USD per month [1]. In addition to the minimum salary, workers greatly rely on bonuses, allowances and overtime work [4,6]. A large part of the earnings made while working in the factories are sent to family members which has an extensive anti-poverty effect there [4–7].

Concerns about the nutritional status of Cambodian garment workers were raised years ago [7]. It has been concluded that a proper diet in terms of quantity and quality is likely to be out of reach for this population group [4,6,7]. Malnutrition among workers has become a sensitive topic, as it has been linked to the mass faintings frequently reported in the factories [4]. The average daily amount of money spent by workers on food (~1.5 USD) has been described as insufficient to ensure an adequate diet [4]. Thrift measures also involve workers skipping meals [4,7]. In 2013, based on a small cross-sectional survey, NGOs reported a prevalence of 36% underweight among female workers [4]. A recent study conducted by the ILO in several Cambodian factories found 14% of workers to be underweight and 45% to be anemic [8]. Finally, the authors of this study reported 31% underweight, 27% anemia and a high prevalence of poor iron status from a factory-based baseline survey among young and nulliparous female garment workers [5].

Malnutrition (underweight, anemia and/or micronutrient deficiencies) among women in reproductive age is associated with impaired cognition, reduced work capacity and higher susceptibility to infections [9–11]. During gestation, it is associated with increased maternal morbidity and mortality, low birth weight, premature delivery and increased fetal and neonatal deaths [9–11].

Nutritional anemia is induced by diets that lack sufficient amounts of essential micronutrients, such as iron, vitamin A (VitA), vitamin B12 (VitB12) or folate, to meet the need for hemoglobin and red blood cell synthesis [9,12]. Non-nutrition factors for anemia are especially hemoglobinopathies, menstrual blood loss, and parasite infestations [9,13,14].

The establishment of staff canteens in Cambodian garment factories has been proposed as a suitable intervention to improve the nutritional and health status of workers, to reduce absenteeism, and to increase productivity [15]. Beyond that, meal provision showed positive effects on dietary diversity, on food security, and on lowering the percentage of employees who have taken loans for food purchases [8]. Still, most of the factories do not hold a canteen (or even an eating area) with the costs being the most critical factor [15]. At present, there is no national legislation obliging factory owners to operate canteens or to provide meals in any other way. Furthermore, national guidelines on meal provision in garment factories do not exist.

In spite of the publication of recent studies from Cambodia touching upon this subject [8,15], detailed information on exemplary meals/menus, their nutritive value and contribution towards recommended dietary allowances (RDAs), as well as their associated costs, are scarce or still missing. However, this information is essential to empower all stakeholders along the Cambodian garment sector to make informed choices on the setup and operation of staff canteens. The current paper reports on the exemplary lunch provision approach within the LUPROGAR study (Lunch Provision in Garment Factories), a factory-based randomized controlled trial, whose primary goal is to determine the impact of daily lunch provision through a staff canteen on the nutritional status (anthropometry and micronutrient status) of female garment workers in Cambodia. Based on food sample data collected during the trial's lunch provision (non-systematic convenience sampling), the main objective of the present study is to determine the nutritive value (energy, macronutrients, dietary fiber and micronutrients) of twelve low-price model lunch sets considering the actual portion sizes.

2. Materials and Methods

2.1. Study Setting

The LUPROGAR trial was implemented during 2015 at Apsara Garment Co. Ltd., an export-oriented garment factory located in the suburban commune Chom Chau in Cambodia's capital Phnom Penh, about 10 km west of the city center. The factory employed some 1300 workers. The majority were young unmarried women from low-income rural households. Conditions of employment were assumed to be comparable with overall working conditions in the garment sector. The factory operated on six workdays per week and was selected purposely since the management was showing interest to collaborate in this research.

Following enrolment and baseline data collection in April 2015 [5], 223 female workers (<31 years old, non-pregnant and nulliparous) were randomly allocated in equal shares into an intervention arm (six months of free lunch provision during workdays) and a control arm (equal monetary compensation at the end of the study). The factory was previously not operating a staff canteen. A temporary canteen (including serving counter, dining area and crockery collecting station, about 100 seats capacity) was installed specifically for the LUPROGAR study. For this purpose, the management provided a roofed outdoor area (around 150 m^2) at the factory site (see Figure 1). All needed materials and furnishing were locally purchased at markets and specialized shops (see Table 1). Total costs per seat amounted to 28 USD.

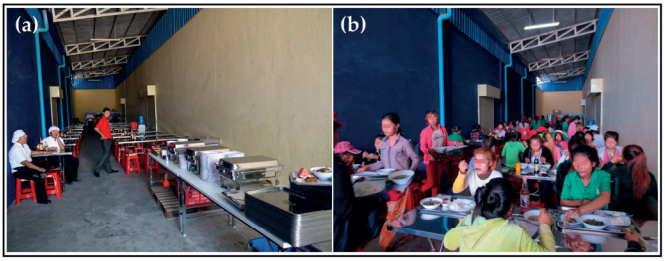

Figure 1. (**a**) Setup of the temporary canteen in a roofed area at factory site; and (**b**) dining area during lunch break (Depicted individuals were anonymized).

Table 1. Costs for the setup of the canteen (circa 100 seats capacity) [1,2].

Materials and Furnishing	Costs (USD)
Dining area	
Tables and chairs	750
Crockery [3]	600
Water dispenser	120
Fans	220
Serving counter	
Tables	250
Gas cooker and supplies	150
Chafing dishes	450
Crockery for food distribution	40
Fire extinguisher	20
Crockery collecting	
Tables	100
Collecting boxes	100
Total	2800 [4]

[1] Roofed outdoor area (around 150 m^2) provided by the factory management; [2] No canteen kitchen at site, daily food delivery from local caterer; [3] Including plates, bowls, cups, cutlery and trays; [4] Costs per seat: 28 USD.

2.2. Lunch Provision

LUPROGAR aimed to serve adequate full lunch sets at reasonable costs (about 1 USD/person/day) in collaboration with Hagar Catering and Facilities Management Ltd., an established canteen service provider from Phnom Penh, Cambodia. First, lunch sets were drafted to be composed of a stir-fry dish, a soup dish, a side item (cooked rice), and a fruit dessert. The aim was to provide approximately 700 kcal/set, about one third of RDA for non-pregnant women aged 19–30 years old [16], in line with foreign guidelines on the caloric value of lunch provision through canteens [17]. A biweekly menu, including twelve model lunch sets, was then outlined in consultation with the caterer (see Table 2). Focus was laid on acceptable Cambodian dishes, on using local foods and on ensuring dietary diversity, by providing cereals, various vegetables, animal source foods (meat or fish), and fresh fruits on a daily basis. After one month of lunch provision, the menu was slightly adjusted according to preferences expressed by workers in a short menu preference questionnaire. Examples of lunch sets are illustrated in Figure 2.

After the setup of the canteen, lunch provision on workdays was carried out by the caterer for the duration of six months (from May until October 2015). Dishes were daily prepared according to consistent recipes at a commercial kitchen located in Phnom Penh's city center and delivered within 1 h to the factory site. In soup dishes, the amount of non-fortified cooking oil per serving was targeted to be ~10 g. Stir-fry and soup dishes were reheated just before serving. The staff was instructed to serve constant portion sizes. At the canteen, workers had free access to drinking water and locally used condiments (non-fortified soy/fish sauce and fresh red chili).

Table 2. Biweekly menu for lunch provision at a garment factory in Phnom Penh, Cambodia [1,2].

Lunch Sets [3]	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Identifier	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**
Stir-fry dish (Week A)	Fried fish *(Trey chien)*	Stir-fried morning glory *(Cha trakuon)*	Omelet with climbing wattle [4] *(Chien pong tea saom)*	Stir-fried choy sum *(Cha spey chong keus)*	Fried fish *(Trey chien)*	Stir-fried mixed vegetables *(Cha bonlai krupmuk)*
Soup dish (Week A)	Vegetable soup with pumpkin *(Samlor brahoeur)*	Winter melon sour soup with fish *(Samlor machu trolach)*	Banana blossom soup with chicken *(Samlor machu trayung chek)*	Morning glory sour soup with pork *(Machu kreung trakuon saichruk)*	Vietnamese vegetable soup *(Machu yuan)*	Spinach soup with minced pork *(Samlor phti snau saichruk)*
Side item (Week A)	Rice, cooked	Rice, cooked	Rice, cooked	Rice, cooked	Rice, cooked	Rice, cooked
Dessert (Week A)	Dragon fruit	Papaya	Banana	Pineapple	Mango	Longan fruit
Identifier	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
Stir-fry dish (Week B)	Fried fish with ginger and soybeans *(Trey chien choun)*	Stir-fried spinach *(Cha phti)*	Fried fish with pickled mango *(Chien trey khlang hai nuong svay)*	Fried chicken wing *(Slap morn bompong)*	Stewed fish *(Trey chien chu em)*	Stir-fried Chinese kale *(Cha kana)*
Soup dish (Week B)	Spicy vegetable soup with sweet potatoes *(Samlor ktis)*	Vegetable soup with pork *(Snau chab chay)*	Morning glory sour soup *(Machu kreung)*	Vegetable soup with green papaya *(Samlor koko)*	Spinach fish soup *(Snau Phti)*	Fish sour soup with onions *(Snau chru trey)*
Side item (Week B)	Rice, cooked	Rice, cooked	Rice, cooked	Rice, cooked	Rice, cooked	Rice, cooked
Dessert (Week B)	Dragon fruit	Papaya	Banana	Pineapple	Mango	Longan fruit

[1] Six workdays per week; [2] Cambodian main dish names in brackets; [3] Stir-fry, soup, side item and fruit dessert; [4] Climbing wattle (*Acacia pennata*) is a shrub-like plant native to South/Southeast Asia, the feathery shoots are used here as a common ingredient.

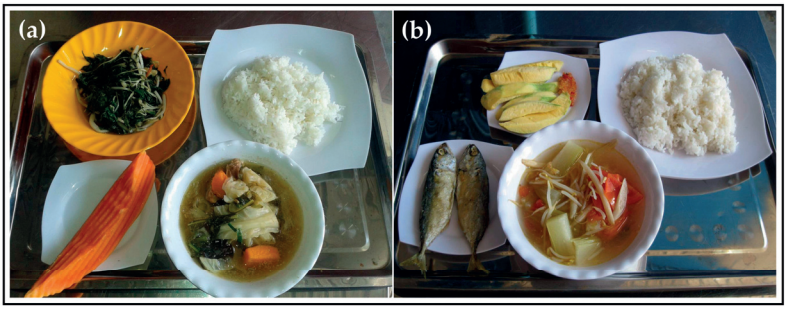

Figure 2. Examples of lunch sets (composed of stir-fry, soup, side item and fruit dessert) served at a garment factory in Phnom Penh, Cambodia: (**a**) stir-fried spinach (*Cha phti*), vegetable soup with pork (*Snau chab chay*), cooked rice and ripe papaya (Set B2); and (**b**) fried fish (*Trey chien*), Vietnamese vegetable soup (*Machu yuan*), cooked rice and mango (Set A5).

The total net price of lunch sets, stipulated by the caterer, amounted to 1.15 USD/person/day and was determined by agreed serving sizes of 50 g animal source foods (0.50 USD), 150 g of vegetables (0.35 USD), 250 g of cooked rice (0.15 USD) and 100 g of fresh fruits (0.15 USD) (see Table 3). Animal source foods belong to the most expensive foods in Cambodia [15,18], explaining the relatively high price for the meat/fish component. The price per lunch set also reflects the relatively small order of about 100 lunch sets/day, as a discount is offered by the caterer with an increasing number ordered. In addition, the above price included delivery, food distribution, and cleaning services on a daily basis, as well as insurance covering eventual costs for treatment in the case of a foodborne disease.

Table 3. Agreed serving sizes and costs of food groups in low-price model lunch sets served at a garment factory in Phnom Penh, Cambodia. [1]

Food Groups	Serving Size (g)	Costs (USD)
Main dishes (stir-fry and soup)		
Meat or fish, cooked or fried	50	0.50
Vegetables, cooked or fried	150	0.35
Cooking oil	10	-
Side item		
Rice, cooked	250	0.15
Dessert		
Various fruits, raw	100	0.15
Total	560	1.15 [2]

[1] According to agreement with caterer at a daily provision of about 100 lunch sets/day; [2] Total price per lunch set, including service costs (delivery, food distribution and cleaning) and insurance, excluding 10% VAT.

2.3. Nutritive Value of Lunch Sets

On 50 days within the course of the six-month lunch provision (about 35% of total trial duration), single or multiple samples among two to all four dish types were taken directly from the service counter (non-systematic convenience sampling, at any arbitrary time of the actual food distribution) and subsequently weighed using a commercial electronic kitchen scale (SensorDisc SF-400, 500 g × 0.1 g, Huiding Hardware, Dongyang, China). Multiple samples per day were generally taken from fruit desserts, from single component dishes (stir-fry dishes such as fried fish, fried chicken wings and

omelet) and from separately prepared fish portions in composite dishes, which were convenient to scale. The total minimum numbers of samples taken for each individual dish type were $n = 5$ for stir-fry dishes, $n = 5$ for soup dishes, $n = 34$ for the side item and $n = 25$ for fruit desserts (see Tables A1 and A2 in Appendix A for exact number of samples). In composite dishes, all measurable ingredients were weighed individually. The amount of broth, if present, was determined by thoroughly decanting samples through a sieve.

Weight data were double entered into Excel spreadsheets and of each ingredient in every individual dish the mean and corresponding standard deviation were calculated (Excel 2013, Microsoft Corp., Redmond, Washington, WA, USA). Mean weights of the daily side item and of the six single fruit desserts are based on the overall number of samples taken in both menu weeks, A and B. Ingredients with a mean weight of $\leq$1.5 g were not considered in further analysis. Due to non-edible parts (skin or shell and seeds), a 30% weight loss was taken into account for two fruit desserts (banana and longan fruit) before further evaluation (based on the mean percentage of non-edible parts determined by weighing among 10 servings of each). All other fruit desserts were served peeled or peeled and seedless. The proportion of ingredients in the omelet dish was roughly estimated to be 80% egg and 20% climbing wattle (shoots of *Acacia pennata*, a shrub-like plant native to South/Southeast Asia).

Mean weights were used to estimate the nutritive value of all twelve lunch sets via NutriSurvey software (Version 29 October 2007, SEAMEO-TROPMED RCCN, University of Jakarta, Indonesia). For this purpose, food composition data for all 57 individual ingredients (data generally available as fresh/raw condition) were inserted into the NutriSurvey database, mainly from Cambodian and ASEAN food composition tables [19,20]. Vietnamese and USDA food composition tables were used for 10 ingredients which were not listed in the Cambodian nor ASEAN database [21,22]. Composition data for pitaya (dragon fruit) were found elsewhere [23]. Due to the limited data among the food composition tables, the nutritive value of lunch sets could only be estimated for energy, protein, fat, carbohydrates, dietary fiber, vitamin C (VitC), iron, VitA, and VitB12. Folate was included as well, although information on folate in the Asian databases was missing for 15 ingredients. Where possible, missing data on the folate content of these ingredients were completed with USDA data [22]. Table 4 shows the corresponding RDAs to calculate each lunch set's contribution towards the RDAs among non-pregnant women aged 19–30 years old.

Table 4. Recommended dietary allowances (RDAs) for energy, macronutrients, dietary fiber, VitC, iron, VitA, folate and VitB12 among non-pregnant women aged 19–30 years old.

Variables	RDA	Source
Energy	2115 kcal/day [1]	[16]
Macronutrients		
Carbohydrates	291 g/day [2]	[24]
Fat	53 g/day [3]	[25]
Protein	50 g/day [1,4]	[16]
Dietary fiber	25 g/day [5]	[26]
Micronutrients		
Vitamin C	70 mg/day [1]	[16]
Iron	29.4 mg/day [1,6]	[16]
Vitamin A (RAE)	500 µg/day [1]	[16]
Folate	400 µg/day [1]	[16]
Vitamin B12	2.4 µg/day	[25]

[1] Based on a body weight of 50 kg; [2] Based on providing 55% of total energy intake; [3] Based on providing 22.5% of total energy intake; [4] Adjusted for 80% protein quality; [5] Adequate intake; [6] Adjusted for 10% bioavailability; RAE: Retinol activity equivalent.

2.4. Ethics

The LUPROGAR trial was approved by the Institutional Review Board of the Faculty of Medicine at Justus Liebig University, Giessen, Germany (14 November 2014) and the National Ethics Committee for Health Research at the Ministry of Health, Phnom Penh, Cambodia (29 December 2014). Written informed consent was collected from all study participants prior to enrolment by signature or fingerprint. Both ethical committees approved the consent format prior to data collection. The study was registered at the German Clinical Trials Register (9 January 2015, Identifier: DRKS00007666).

3. Results

3.1. Amount of Food Groups/Ingredients in Lunch Sets

Tables A1 and A2 (see Appendix A) illustrate the amounts by weight of individual ingredients for each lunch set provided during menu weeks A and B, respectively.

The mean weight of the meat/fish component in sets ranged from 64 ± 17 g (stir-fry dish in Set B3) to 15 ± 8 g (soup dish in Set A6), which was distinctly less than the agreed serving size of 50 g. However, in most of the sets, the mean weight of the meat/fish component was about 50 +/− 10 g.

The total amount of vegetables provided with each lunch set (not separately shown here, based on the sum of mean weights of vegetables in both main dishes) varied considerably from 270 g (Set B2) to 93 g (Set A3). In general, more than the agreed serving size of 150 g vegetables was served. The highest amounts (>200 g) were found in lunch sets in which dark green leafy vegetables (DGLVs) or mixed vegetables were served as stir-fry dish (Sets A2, A4, A6 and B2). Moreover, in some soup dishes (Sets A1 and B4), as a common practice in Cambodia, considerable amounts of fresh DGLVs were added at serving (indicated as raw).

Broth (meat/fish based) was a main ingredient of soup dishes, with mean weights between 231 ± 31 g (Set A6) and 165 ± 25 g (Set A5). Further ingredients in main dishes included considerable amounts of egg (Set A3), fruits like pineapple and mango (Sets A5, A6, B1 and B3), sweet potato (Sets B1 and B5), soybeans (Set B1) and mushrooms (Sets B2 and B6). The mean amount of cooked rice was 279 ± 30 g, slightly higher than the agreed serving size of 250 g. Portion sizes of the fruit desserts ranged from 153 ± 38 g (papaya in Sets A2 and B2) to 82 ± 12 g (mango in Sets A5 and B5). Nonetheless, the agreed serving size of 100 g of fresh fruit was reached in four out of six desserts.

3.2. Nutritive Value of Lunch Sets: Calories, Macronutrients and Dietary Fiber

The nutrient contents calculated for each lunch set are summarized in Table 5. In addition, Figure 3 shows the overall mean and range of the percentage contribution towards RDAs for all twelve sets. Compared to the micronutrients considered, the mean amounts of calories, macronutrients and dietary fiber remained rather constant and showed a lower variability.

Total energy content of the sets ranged from 591 kcal (Set A6, 28% of RDA) to 793 kcal (Set B1, 38% of RDA). In contrast to menu Week A, slightly higher values (730–793 kcal) were determined in four out of six sets from menu Week B. The side item (~280 g of cooked rice) provided the largest share of calories, roughly 360 kcal/set. On average, lunch sets provided 697 kcal (33% of RDA), with ~61% of calories derived from carbohydrates, ~23% from fats and ~13% from proteins (data not shown here). The amount of carbohydrates (100–112 g) was consistent among the majority of lunch sets (equaling 34–39% of RDA). Similar to the caloric value, the bulk of carbohydrates was provided with the portion of cooked rice (~82 g). Set B1 provided a slightly higher amount of carbohydrates (123 g, 42% of RDA), which was related to the amount of sweet potato used in the corresponding soup dish. Mean amount of carbohydrates among all sets was 107 g (37% of RDA).

The quantity of protein varied from 16 g (Set A6, 32% of RDA) to 30 g (Set B2, 60% of RDA). The low amount of protein in Set A6 was related to the relatively small amount of meat served with the corresponding soup dish. Still, most of the lunch sets contained 22–26 g of protein, which equaled 44–52% of recommended daily protein intake. In general, main protein sources were meat and fish.

The mean amount among all sets was 23 g (46% of RDA). The fat content ranged from 12 g (Set A6, 23% of RDA) to 24 g (Set B4, 45% of RDA). The mean amount of fat was 18 g (34% of RDA). Slightly higher amounts (≥20 g) were noted in sets where fried fish (Sets A1, A5, B1), fried egg (Set A3) or fried meat (Set B4) were served as stir-fry dish. Lower amounts (<15 g) were calculated for sets including DGLVs (Sets A2, A4, B6) or mixed vegetables (Set A6) as stir-fry.

Lunch sets contained 6 g (Sets A3, A5, B4 and B6, 24% of RDA) to 12 g (Set B2, 48% of RDA) of dietary fiber, whereby DGLVs, fruits and rice were the main sources. On average, sets contained 8 g (32% of RDA) of fiber.

Table 5. Estimated nutritive value of low-price model lunch sets provided at a garment factory in Phnom Penh, Cambodia (menu Weeks A and B) [1,2].

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Identifier, Lunch Sets Week A	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**
Nutritive value						
Energy, kcal (% of RDA)	699 (33)	651 (31)	704 (33)	639 (30)	708 (34)	591 (28)
Carbohydrates, g (% of RDA)	101 (35)	100 (34)	103 (35)	104 (36)	103 (35)	102 (35)
Protein, g (% of RDA)	22 (44)	22 (44)	23 (46)	22 (44)	26 (52)	16 (32)
Fat, g (% of RDA)	21 (40)	14 (26)	20 (38)	13 (25)	20 (38)	12 (23)
Dietary fiber, g (% of RDA)	7 (28)	10 (40)	6 (24)	8 (32)	6 (24)	7 (28)
Vitamin C, mg (% of RDA)	47 (67)	167 (239)	24 (34)	206 (294)	75 (107)	106 (151)
Iron, mg (% of RDA)	4 (14)	8 (27)	4 (14)	9 (31)	4 (14)	7 (24)
Vitamin A (RAE), µg (% of RDA)	136 (27)	505 (101)	152 (30)	604 (121)	127 (25)	365 (73)
Folate, µg (% of RDA)	29 (7)	141 (35)	75 (19)	344 (86)	74 (19)	239 (60)
Vitamin B12, µg (% of RDA)	0.7 (29)	0.9 (38)	0.5 (21)	0.4 (17)	1.5 (63)	0.2 (8)
Identifier, Lunch Sets Week B	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
Nutritive value						
Energy, kcal (% of RDA)	793 (38)	749 (35)	730 (35)	765 (36)	686 (32)	646 (31)
Carbohydrates, g (% of RDA)	123 (42)	101 (35)	112 (39)	112 (39)	112 (39)	106 (36)
Protein, g (% of RDA)	23 (46)	30 (60)	24 (48)	24 (48)	24 (48)	24 (48)
Fat, g (% of RDA)	22 (42)	22 (42)	18 (34)	24 (45)	14 (26)	14 (26)
Dietary fiber, g (% of RDA)	10 (40)	12 (48)	8 (32)	6 (24)	8 (32)	6 (24)
Vitamin C, mg (% of RDA)	118 (169)	212 (303)	56 (80)	55 (79)	92 (131)	177 (253)
Iron, mg (% of RDA)	5 (17)	12 (41)	6 (20)	4 (14)	6 (20)	6 (20)
Vitamin A (RAE), µg (% of RDA)	61 (12)	799 (160)	340 (68)	142 (28)	372 (74)	370 (74)
Folate, µg (% of RDA)	43 (11)	477 (120)	126 (32)	97 (24)	210 (53)	245 (61)
Vitamin B12, µg (% of RDA)	0.6 (25)	0.4 (17)	1.2 (50)	0.3 (13)	1.2 (50)	1.0 (42)

[1] Based on mean weights of ingredients in lunch sets; [2] In relation to RDAs as described in methods section; kcal: Kilocalories; RAE: Retinol activity equivalent; RDA: Recommended dietary allowance.

3.3. Nutritive Value of Lunch Sets: VitC, Iron, VitA, Folate and VitB12

Total VitC content varied considerably from 24 mg (Set A3, 34% of RDA) to 212 mg (Set B2, 303% of RDA). The richest sources were fruits (e.g., papaya and longan fruit) and vegetables (e.g., DGLVs). The average amount of VitC was 111 mg, which equaled 159% of recommended daily intake. The amount of iron in lunch sets ranged from 4 mg (Sets A1, A3, A5 and B4, 14% of RDA) to 12 mg (Set B2, 41% of RDA). DGLVs, some fruits, rice and meat/fish were the primary iron sources. The average amount was 6 mg, equaling only 20% of RDA.

The VitA content ranged greatly from 61 µg (Set B1, 12% of RDA) to 799 µg RAE (Set B2, 160% of RDA). Lunch sets including DGLVs such as morning glory (Sets A2, A4 and B3) choy sum (Set A4), spinach (Sets A6, B2, B5), or Chinese kale (Set B6) as main ingredients in stir-fry or soup dishes, were estimated to provide highest amounts of VitA (68–160% of RDA). Mean amount among sets was 331 µg RAE (66% of RDA).

The estimated amount of folate varied from 29 µg (Set A1, 7% of RDA) to 477 µg (Set B2, 120% of RDA). DGLVs and fruits were the main sources. Average amount among lunch sets was 175 µg, equaling 44% of RDA. The VitB12 content ranged from 0.2 µg (Set A6, 8% of RDA) to 1.5 µg (Set A5, 63% of RDA). Mean amount was 0.7 µg (29% of RDA). Lunch sets containing fish (Sets A1, A2, A5, B3,

B5 and B6) were calculated to provide ≥0.7 µg of VitB12, compared to sets including pork or chicken meat (Sets A3, A4, A6, B2 and B4), providing lower amounts of VitB12.

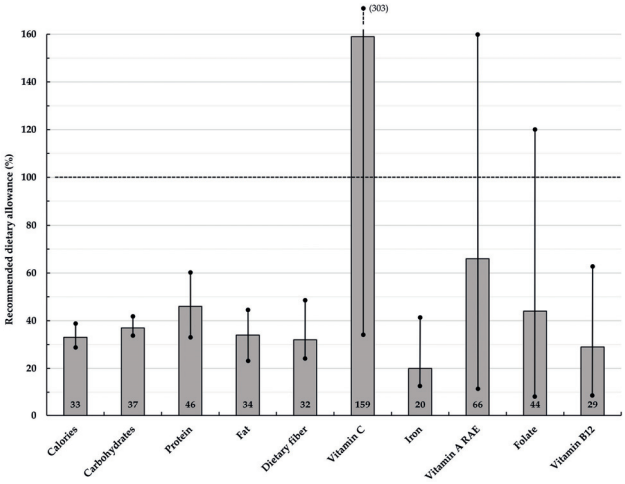

Figure 3. Mean contribution of lunch sets towards RDAs among non-pregnant women aged 19–30 years old. Lines within bars illustrate the range; RAE: Retinol activity equivalent.

4. Discussion

The present paper provides information on the caloric, macronutrient and micronutrient content of twelve low-price model lunch sets served to female garment workers in Cambodia. The assessment of the nutritive value is based on actual serving sizes determined during a six-month period in collaboration with an established commercial caterer. Food samples for analysis were obtained directly from the serving counter.

The caloric content of lunch sets accounted for about one-third of the recommended daily energy intake on average (697 of 2115 kcal/day), matching well the initially targeted goal for caloric value. It was estimated that ~61% of calories were provided by carbohydrates, ~23% by fat and ~13% by protein (data not shown here), which corresponds with FAO/WHO recommendations for sources of energy intake [27]. On the other hand, slightly different contributions, namely 50% from carbohydrates, 30% from fat and 20% from protein, have been proposed as an optimal macronutrient distribution [17]. Given the high prevalence of workers who showed a body-mass-index of less than 18.5 kg/m^2 at LUPROGAR's baseline survey [5], it remains unresolved if these average amount of 700 kcal per lunch is suitable to improve the nutritional status of workers affected by underweight. Quantitative data on the total daily dietary intake of Cambodian garment workers are still missing, both in general and in relation to their working conditions. However, those data are needed to evaluate the energy intake during lunch provision for dietary adequacy. Moreover, the RDA of 2115 kcal/day [16] might underestimate energy requirements among workers exposed to heavy work load and/or overtime work [25–27].

As for the caloric value of lunch sets, the estimated mean amount of carbohydrates (107 g), fat (18 g) and dietary fiber (8 g), each equaled roughly one-third of RDA (adequate intake with regard to dietary fiber). Contribution towards the RDA of protein was slightly higher (46%, 23 g of protein on average), which is regarded as beneficial, since protein intake among workers might be limited throughout the day due to the relatively high price of most animal source foods in Cambodia [15,18].

In summary, the amounts of macronutrients and dietary fiber provided by the exemplary sets seem to be balanced and sufficient. However, they would need to be adjusted if a higher caloric content of lunch sets is required. The limited extent of the accessible local food composition tables did not allow further characterization with respect to protein quality and composition of carbohydrates and fatty acids [19–21]. Nonetheless, total amounts of sugars (mainly derived from fruits) and saturated fatty acids (mainly derived from cooking oil and flesh meat) are considered to be within an acceptable range.

Compared to the macronutrients, the contribution of lunch sets towards RDAs of selected micronutrients showed a higher variability. Sets were estimated to provide a relatively high amount of VitC, on average 159% of RDA (111 mg), although values among single sets ranged substantially (34–303% of RDA). Intakes above current VitC RDAs have shown lowering effects on, for example, hypertension, endothelial dysfunction and chronic inflammation, independent risk factors for cardiovascular diseases and some cancers [28]. On the other hand, since composition data for many ingredients were only available as in fresh/raw condition, the estimations might likely overestimate total VitC content (in particular for vegetables and fruits in cooked or fried dishes). Despite the obvious lowering effect of boiling and frying [29], it is assumed that a sufficient amount of VitC is provided with lunch sets.

Average total iron content among sets was relatively low (6 mg) and equaled only 20% of RDA (assuming low bioavailability of 10%), which might not be adequate. Hence, it is doubted that the iron status of female garment workers could be improved. About two-third of LUPROGAR's participants showed iron deficiency or a marginal iron status at baseline, but this information was not available at the time of the lunch sets planning. At least, a pajrt of the high prevalence of anemia is attributable to iron deficiency [5]. Most of the dietary iron was provided as less bioavailable nonheme iron, mainly derived from vegetables (especially iron-rich DGLVs, e.g., morning glory, spinach, and Chinese kale), fruits, and rice. On the other hand, VitC, present in adequate amounts, enhances nonheme iron absorption, but effects on iron absorption might be less pronounced in a complete diet including various dietary inhibitors [30,31]. Chicken and pork meat, as well as the various fish species, served in small portion sizes of ~50 g due to the relatively high price, have a low iron content (0.5–1.7 mg/100 g edible portion) [19–21]. Although iron bioavailability is higher from animal source foods [32–34], increasing the portion size of these foods would significantly increase the costs per meal. Other strategies to increase the iron content among the proposed lunch sets would be to include blood curd and liver (e.g., from chicken and pork) as common heme iron-rich food ingredients (up to 15 mg/100 g) in Southeast Asia [32]. They could be easily incorporated into single dishes and small amounts would already significantly increase the iron content of the lunch sets. Another food-based approach could be the incorporation of a locally available and traditionally used small fish, Mekong flying barb (*Esomus longimanus*) with a high total iron content of ~11 mg/100 g [35,36]. An alternative strategy could be the provision of iron-fortified fish/soy sauce or the use of iron-fortified rice [37,38]. However, assuming an average consumption of 5 g of fish/soy sauce during lunch, the utilization of iron-fortified sauces would only result in a modest increase in total iron content of 1.5 mg/lunch set (at fortification of ~300 mg iron/kg [37]). Moreover, alongside a national fortification program, undesired levels of nitrogen and salt content among iron-fortified sauces have been recently reported from Cambodia [37]. In addition, multi-micronutrient fortified rice (containing 7–11 mg iron/100 g uncooked rice) has been associated with increased risk of hookworm infections and showed only limited impact on improving the iron status of Cambodian school children [39,40].

The model lunch sets contained a relatively high amount of RAE on average (331 µg, equaling 66% of RDA). Still, VitA content also varied strongly (61–799 µg RAE), depending on the presence and portion size of various vegetables (e.g., DGLVs) and/or fruits (e.g., papaya) rich in provitamin A carotenoids. Both are accessible at a relatively low price and are part of the traditional Cambodian diet [18]. This illustrates how the proposed low-priced lunch sets contribute to an adequate VitA intake. However, the range of absorption and bioconversion of provitamin A carotenoids to VitA from various vegetables (compared to preformed VitA from animal source foods) can be low for DGLVs

and other vegetables [41]. On the other hand, cooking and heat processing often result in greater bioavailability [29,41]. Nevertheless, at LUPROGAR's baseline survey, female garment workers were not affected by VitA deficiency, and only a low prevalence of marginal VitA status was observed (<10%) [5].

The estimated mean folate content among sets was 175 µg, corresponding to 44% of RDA, which seems an adequate amount on average. Yet, single values ranged from 29–477 µg (7–120% of RDA), whereby DGLVs and fruits were the main sources again. The low amount in two sets, namely A1 (29 µg) and B1 (43 µg), may be due to underestimation, as data on folate content was missing for the corresponding fruit dessert (dragon fruit). The same applies for Sets A6 and B6 (folate data missing for longan). Folate deficiency is prevalent among Cambodian women, and measures to increase folate/folic acid intake have been suggested for interventions targeting the high prevalence of anemia [42].

On average, the sets contained 0.7 µg of VitB12 (29% of RDA). This amount appears to be adequate, since VitB12 deficiency among female workers was not found at LUPROGAR's baseline survey, nor in national representative data among women of reproductive age [5,42]. Variations in VitB12 content were noted for different types of animal source foods. In lunch sets including fish, more VitB12 was found than in lunch sets with chicken or pork meat. The low VitB12 content in Set A6 was mainly related to the low quantity of meat in the corresponding soup dish. The loss of VitB12 from fish by various cooking methods seems to be low (2–15%); however, VitB12 bioavailability might be slightly lower than from flesh meats [43]. Unlike various flesh meats, fish is an affordable and widely consumed food, even among the socioeconomically disadvantaged populations in Cambodia [18,35]. It is assumed that a regular consumption of fresh and processed fish, also at meals outside the working hours, ensures an adequate VitB12 intake.

Limitations of the Study

Unfortunately, the recipes for the model lunch sets do not rest upon LUPROGAR's baseline findings regarding the nutritional and/or micronutrient status of participants [5], nor on any other previously conducted gap-oriented assessment. Since most of the analyses of the participants' initial micronutrient status had to be conducted abroad, the results were available months later.

The food composition assessment was solely focused on the provision through lunch sets and did not account for actual food leftovers (which, by plain observation, were estimated as very low). This is a limitation of the study, as contributions to RDAs are estimated based on the assumption that workers consumed the full meal.

A major limitation affecting the accuracy of the estimated mean nutritive values of single and all lunch sets was the non-systematic convenience sampling during the lunch provision (ranging from $n = 5$ for some stir-fry/soup dishes to $n = 52$ for a fresh fruit dessert). The small sample size among stir-fry/soup dishes partly led to large standard deviations when assessing the weight of individual ingredients in lunch sets. A systematic and consistent sampling would have been favorable, but unfortunately it could not be implemented within the study. Nevertheless, it is assumed that overall conclusions regarding the nutritive value of lunch sets are valid and informative.

The local food composition tables (Cambodian, ASEAN and Vietnamese) had a limited extent in terms of analysis and number of food items [19–21]. For this reason, the USDA food composition table was used for some ingredients (<10 items) [22]. The estimation of the nutritive value was therefore restricted and no statements could be made for protein quality, for composition of carbohydrates and fatty acids, and for components known to inhibit iron uptake [33,34]. Many food composition data were only available for fresh/raw condition, blending out the effect of cooking methods on the nutrient content. Finally, missing folate data for a few foods certainly led to an underestimation for some lunch sets.

5. Conclusions

Given the nutritional situation of Cambodian garment workers, meal provision through staff canteens is expected to bear the potential to improve food security of workers, approximately at costs of less than 1 USD/person/day (at large-scale). The estimations made here regarding the nutritive value of low-price model lunch sets provide a basis to review ongoing or planned lunch provision. Further research should focus on collecting data on quantitative total dietary intake as well as physical activity with respect to demanding working conditions. With such data, the concept of lunch provision could be further optimized.

LUPROGAR's exemplary lunch sets for female garment workers matched foreign recommendations regarding their contribution to RDAs of caloric content and macronutrient composition for sources of energy intake. However, the micronutrient content revealed a low iron content in lunch sets. Thus, strategies are needed to increase the provision of iron. It is assumed that the incorporation of alternative and affordable iron-rich food items would be better suited to significantly increase the iron content than just increasing the serving sizes of rather costly meat/fish components in lunch sets. On the other hand, it is considered that model lunch sets contained beneficial and adequate amounts of VitC, VitA, folate and VitB12, on average. Considering the year-round availability and relatively low price for various vegetables and fruits in Cambodia, it should be feasible to ensure a suitable content of VitC, VitA and folate in meals served to workers through staff canteens.

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Author Contributions: J.M. and M.B.K. conceived and designed the LUPROGAR trial; J.M. conducted the food sample collection and managed the data; F.W. and C.C. supervised data collection in the field; J.M. and A.P. conducted the analysis of the data; J.M. wrote the manuscript; F.W. and M.B.K. contributed to the review and editing of the manuscript to the final version; and J.M. and M.B.K. had primary responsibility for the final content. All authors read and approved the final version of the manuscript.

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Abbreviations

The following abbreviations are used in this manuscript:

USD	United States Dollar
NGO	Non-government organization
ILO	International Labour Organization
VitA	Vitamin A
VitB12	Vitamin B12
RDA	Recommended dietary allowance
LUPROGAR	Lunch Provision in Garment Factories
Kcal	Kilocalories
VAT	Value added tax
ASEAN	Association of Southeast Asian Nations
USDA	United States Department of Agriculture
VitC	Vitamin C
RAE	Retinol activity equivalent
DGLV	Dark green leafy vegetable
FAO	Food and Agriculture Organization of the United Nations
WHO	World Health Organization
SD	Standard deviation

Appendix A

Table A1. Amount by weight of ingredients in low-price model lunch sets served at a garment factory in Phnom Penh, Cambodia (Week A) [1,2].

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Identifier	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**
Stir-fry dish, Week A Samples weighed	**Fried fish** $n = 22$	**Stir-fried morning glory** $n = 5$	**Omelet with climbing wattle** $n = 20$	**Stir-fried choy sum** $n = 5$	**Fried fish** $n = 24$	**Stir-fried mixed vegetables** $n = 5$
Ingredients (mean weight ± SD)	Snail eating barb fish, whole, fried (44 ± 12 g)	Morning glory, fried (119 ± 24 g) Vegetable broth (33 ± 24 g)	Egg omelet, fried (48 ± 13 g) [3] Climbing wattle, fried (12 ± 3 g) [3]	Choy sum, fried (138 ± 20 g) Vegetable broth (76 ± 10 g)	Short mackerel fish, whole, fried (61 ± 11 g)	Tomato, fried (48 ± 11 g) Vegetable broth (46 ± 10 g) Onion, fried (33 ± 7 g) Cucumber, fried (25 ± 3 g) Pineapple, fried (15 ± 13 g) Chinese kale, fried (7 ± 3 g)
Soup dish, Week A Samples weighed	**Vegetable soup with pumpkin** $n = 8$	**Winter melon sour soup with fish** $n = 8$	**Banana blossom soup with chicken** $n = 8$	**Morning glory sour soup with pork** $n = 6$	**Vietnamese vegetable soup** $n = 5$	**Spinach soup with minced pork** $n = 5$
Ingredients (mean weight ± SD)	Meat broth (185 ± 17 g) Sponge gourd, cooked (65 ± 32 g) Winter melon, cooked (51 ± 27 g) Pumpkin, cooked (31 ± 22 g) Ivy gourd leaves, raw (24 ± 7 g) Vegetable oil (10 g) [4] Oyster mushroom, cooked (3 ± 3 g)	Fish broth (176 ± 30 g) Winter melon, cooked (134 ± 29 g) Giant snake head fish steak, cooked (38 ± 9 g) Vegetable oil (10 g) [4] Rice paddy herb, raw (9 ± 6 g) Red chili, raw (5 ± 3 g)	Meat broth (225 ± 28 g) Banana blossom, cooked (69 ± 26 g) Chicken meat, cooked (33 ± 12 g) Vegetable oil (10 g) [4] Long coriander, raw (6 ± 7 g) Thai basil, raw (4 ± 6 g) Red chili, raw (3 ± 2 g)	Meat broth (172 ± 38 g) Morning glory, cooked (117 ± 23 g) Pork meat, cooked (31 ± 8 g) Vegetable oil (10 g) [4]	Meat broth (165 ± 25 g) Tomato, cooked (69 ± 31 g) Winter melon, cooked (64 ± 8 g) Pineapple, cooked (13 ± 17 g) Vegetable oil (10 g) [4] Lotus root, cooked (7 ± 6 g) Rice paddy herb, raw (7 ± 5 g) Soybean sprouts, cooked (6 ± 7 g) Long coriander, raw (3 ± 5 g)	Meat broth (231 ± 31 g) Spinach, cooked (103 ± 13 g) Pork meat, minced, cooked (15 ± 8 g) Vegetable oil (10 g) [4]
Side item Samples weighed	**Rice**	**Rice**	**Rice** $n = 34$ [5]	**Rice**	**Rice**	**Rice**
Ingredient (mean weight ± SD)	Rice, cooked (279 ± 30 g)					
Dessert Samples weighed	**Fresh fruit** $n = 42$ [5]	**Fresh fruit** $n = 38$ [5]	**Fresh fruit** $n = 52$ [5]	**Fresh fruit** $n = 37$ [5]	**Fresh fruit** $n = 25$ [5]	**Fresh fruit** $n = 25$ [5]
Ingredient (mean weight ± SD)	Dragon fruit, raw (88 ± 15 g)	Papaya, ripe, raw (153 ± 38 g)	Banana, raw (102 ± 19 g) [6]	Pineapple, raw (102 ± 33 g)	Mango, unripe, raw (82 ± 12 g)	Longan, raw(99 ± 7 g) [6]

[1] Each lunch set composed of stir-fry dish, soup dish, side item and fruit dessert; [2] Mean weights of ingredients used for the estimation of nutritive value of lunch sets; [3] Estimated amount of weight (omelet with 80% egg, 20% climbing wattle); [4] Estimated amount of weight according to agreement with caterer; [5] Overall number of samples taken in both menu weeks (Weeks A and B); [6] In further analysis adjusted for 30% weight loss due to non-edible parts (skin or shell and seeds), all other fruit desserts were served peeled or peeled and seedless; SD: Standard deviation.

Table A2. Amount by weight of ingredients in low-price model lunch sets served at a garment factory in Phnom Penh, Cambodia (Week B). [1,2]

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Identifier	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
Stir-fry dish, Week B	**Fried fish with ginger and soybeans**	**Stir-fried spinach**	**Fried fish with pickled mango**	**Fried chicken wing**	**Stewed fish**	**Stir-fried Chinese kale**
Samples weighed	$n = 5$	$n = 5$	$n = 5$	$n = 15$	$n = 5$	$n = 5$
Ingredients (mean weight ± SD)	Snail eating barb fish, whole, fried (43 ± 19 g) [3] Onion, fried (28 ± 12 g) Ginger, fried (20 ± 4 g) Soybean, fermented, fried (16 ± 4 g)	Spinach, fried (136 ± 16 g) Vegetable broth (27 ± 28 g) Red chili, fried (2 ± 2 g)	Climbing perch fish, whole, fried (64 ± 17 g) [3] Mango, unripe, raw (54 ± 36 g) Tomato, raw (10 ± 10 g) Red chili, raw (3 ± 3 g)	Chicken wing, fried (61 ± 11 g)	Tomato, cooked (75 ± 25 g) Giant snake head fish, steak, cooked (48 ± 14 g) [3] Fish broth (44 ± 31 g)	Chinese kale, fried (115 ± 7 g) Vegetable broth (45 ± 13 g) Red chili, fried (2 ± 2 g)
Soup dish, Week B	**Spicy vegetable soup with sweet potatoes**	**Vegetable soup with pork**	**Morning glory sour soup**	**Vegetable soup with green papaya**	**Spinach fish soup**	**Fish sour soup with onions**
Samples weighed	$n = 7$	$n = 6$	$n = 7$	$n = 7$	$n = 5$	$n = 5$
Ingredients (mean weight ± SD)	Meat broth (175 ± 22 g) Sweet potato, white, cooked (79 ± 43 g) Green bell pepper, cooked (33 ± 15 g) Red bell pepper, cooked (26 ± 22 g) Pineapple, cooked (22 ± 11 g) Vegetable oil (10 g) [4]	Meat broth (182 ± 33 g) Chinese cabbage, cooked (42 ± 40 g) Chinese kale, cooked (37 ± 18 g) Winter melon, cooked (28 ± 25 g) Pork meat, cooked (26 ± 18 g) Carrot, cooked (22 ± 15 g) Fried pork skin, cooked (20 ± 13 g) Wood ear mushroom, cooked (20 ± 16 g) Vegetable oil (10 g) [4] Spring onion, cooked (3 ± 3 g)	Meat broth (215 ± 35 g) Morning glory, cooked (121 ± 20 g) Vegetable oil (10 g) [4]	Meat broth (200 ± 29 g) Papaya, unripe, cooked (78 ± 34 g) Pumpkin, cooked (23 ± 13 g) Jackfruit, unripe, cooked (23 ± 23 g) Ivy gourd leaves, raw (21 ± 7 g) Eggplant, cooked (16 ± 14 g) Vegetable oil (10 g) [4] Long beans, cooked (7 ± 5 g) Moringa leaves, raw (6 ± 6 g)	Fish broth (181 ± 32 g) Spinach, cooked (70 ± 26 g) Sweet potato, white, cooked (50 ± 57 g) Vegetable oil (10 g) [4] Giant snake head fish, steak, cooked (5 ± 6 g)	Fish broth (207 ± 25 g) Giant snake head fish, steak, cooked (44 ± 14 g) [3] Onion, cooked (31 ± 13 g) Oyster mushroom, cooked (25 ± 16 g) Vegetable oil (10 g) [4] Long coriander, raw (3 ± 3 g) Thai basil, raw (2 ± 2 g) Red chili, raw (2 ± 1 g)
Side item Samples weighed	**Rice**	**Rice**	**Rice** $n = 34$ [5]	**Rice**	**Rice**	**Rice**
Ingredient (mean weight ± SD)	Rice, cooked (279 ± 30 g)					
Dessert Samples weighed	**Fresh fruit** $n = 42$ [5]	**Fresh fruit** $n = 38$ [5]	**Fresh fruit** $n = 52$ [5]	**Fresh fruit** $n = 37$ [5]	**Fresh fruit** $n = 25$ [5]	**Fresh fruit** $n = 25$ [5]
Ingredient (mean weight ± SD)	Dragon fruit, raw (88 ± 15 g)	Papaya, ripe, raw (153 ± 38 g)	Banana, raw (102 ± 19 g) [6]	Pineapple, raw (102 ± 33 g)	Mango, unripe, raw (82 ± 12 g)	Longan, raw (99 ± 7 g) [6]

[1] Each lunch set composed of stir-fry dish, soup dish, side item and fruit dessert; [2] Mean weights of ingredients used for the estimation of nutritive value of lunch sets; [3] Number of samples of fish component, $n = 20$; [4] Estimated amount of weight according to agreement with caterer; [5] Overall number of samples taken in both menu weeks (Weeks A and B); [6] In further analysis adjusted for 30% weight loss due to non-edible parts (skin or shell and seeds), all other fruit desserts were served peeled or peeled and seedless; SD: Standard deviation.

References

1. International Labour Organization. *Cambodian Garment and Footwear Sector Bulletin. Issue 5. Recent Trade Policy Developments and Possible Implications for Cambodia's Garment and Footwear Sector*; International Labour Organization: Phnom Penh, Cambodia, 2017.
2. Asuyama, Y.; Neou, S. How has the Cambodian garment industry evolved? In *Dynamics of the Garment Industry in Low-Income Countries: Experience of Asia and Africa*; Fukunishi, T., Ed.; Japan External Trade Organization: Chiba, Japan, 2012.
3. Bargawi, O. *Cambodia's Garment Industry—Origins and Future Prospects*; Overseas Development Institute: London, UK, 2005.
4. McMullen, A. Shop'til They Drop: Fainting and Malnutrition in Garment Workers in Cambodia. In *Labour behind the Label*; Community Legal Education Centre: Phnom Penh, Cambodia, 2013; Available online: https://www.cleanclothes.org/resources/national-cccs/shop-til-they-drop (accessed on 28 January 2016).
5. Makurat, J.; Friedrich, H.; Kuong, K.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Nutritional and micronutrient status of female workers in a garment factory in Cambodia. *Nutrients* **2016**, *8*, 694. [CrossRef] [PubMed]
6. Kang, C.; Liv, D. *Living Wage Survey for Cambodia's Garment Industry*; Cambodia Institute of Development Study: Phnom Penh, Cambodia, 2009; Available online: http://www.fes.or.id/fes/download/Survey_Result_Cambodia.pdf (accessed on 18 May 2016).
7. International Labour Organization; World Bank. *Cambodia—Women and Work in the Garment Industry*; International Labour Organization: Phnom Penh, Cambodia, 2006.
8. International Labour Organization. *Garment Workers' Health and Nutrition Status, and Food Provision in Factories. A Study from Selected Enterprises in Cambodia*; International Labour Organization: Phnom Penh, Cambodia, 2016.
9. World Health Organization. *Iron Deficiency Anaemia. Assessment, Prevention, and Control: A Guide for Programme Managers*; World Health Organization: Geneva, Switzerland, 2001.
10. World Health Organization. *Physical Status: The Use and Interpretation of Anthropometry*; World Health Organization: Geneva, Switzerland, 1995.
11. Black, R.E.; Victora, C.G.; Walker, S.P.; Bhutta, Z.A.; Christian, P.; De Onis, M.; Ezzati, M.; Grantham-McGregor, S.; Katz, J.; Martorell, R.; et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* **2013**, *382*, 427–451. [CrossRef]
12. Koury, M.J.; Ponka, P. New insights into erythropoiesis: The roles of folate, vitamin B12, and iron. *Annu. Rev. Nutr.* **2004**, *24*, 105–131. [CrossRef] [PubMed]
13. Charles, C.V.; Summerlee, A.J.; Dewey, C.E. Anemia in Cambodia: Prevalence, etiology and research needs. *Asia Pac. J. Clin. Nutr.* **2012**, *21*, 171–181. [PubMed]
14. Karakochuk, C.D.; Whitfield, K.C.; Barr, S.I.; Lamers, Y.; Devlin, A.M.; Vercauteren, S.M.; Kroeun, H.; Talukder, A.; McLean, J.; Green, T.J. Genetic hemoglobin disorders rather than iron deficiency are a major predictor of hemoglobin concentration in women of reproductive age in rural Prey Veng, Cambodia. *J. Nutr.* **2015**, *145*, 134–142. [CrossRef] [PubMed]
15. BDLINK; HRINC. *Study on the Perceptions of Garment Factory Owners on Nutrition and the Feasibility for Pursuing Canteen Services in the Garment Sector in Cambodia*; International Labour Organization: Phnom Penh, Cambodia, 2012.
16. Barba, C.V.; Cabrera, M.I. Recommended dietary allowances harmonization in Southeast Asia. *Asia Pac. J. Clin. Nutr.* **2008**, *17*, 405–408. [PubMed]
17. German Nutrition Society. *DGE-Qualitätsstandard für die Betriebsverpflegung*; German Nutrition Society: Bonn, Germany, 2015.
18. Wallace, L.J.; Summerlee, A.J.; Dewey, C.E.; Hak, C.; Hall, A.; Charles, C.V. Women's nutrient intakes and food-related knowledge in rural Kandal province, Cambodia. *Asia Pac. J. Clin. Nutr.* **2014**, *23*, 263–271. [PubMed]
19. SMILING Consortium Group. *Food Composition Table for Cambodia*; Food and Agricultural Organization: Rome, Italy, 2013; Available online: http://www.fao.org/infoods/infoods/tables-and-databases/asia/en/ (accessed on 26 October 2016).

20. Institute of Nutrition; Mahidol University. *ASEAN Food Composition Database. Electronic Version 1, February, 2014*; Institute of Nutrition, Mahidol University: Bangkok, Thailand, 2014; Available online: http://www.inmu.mahidol.ac.th/aseanfoods/doc/OnlineASEAN_FCD_V1_2014.pdf (accessed on 26 October 2016).
21. National Institute of Nutrition Vietnam. *Nutritive Composition Table of Vietnamese Foods*; National Institute of Nutrition Vietnam: Hanoi, Vietnam, 2000.
22. Agricultural Research Service, United States Department of Agriculture. *USDA Food Composition Databases*; United States Department of Agriculture: Washington, DC, USA, 2016. Available online: https://ndb.nal.usda.gov/ndb/ (accessed on 26 October 2016).
23. Nurul, S.R.; Asmah, R. Variability in nutritional composition and phytochemical properties of red pitaya (Hylocerus polyrhizus) from Malaysia and Australia. *Int. Food Res. J.* **2014**, *21*, 1689–1697.
24. Nishida, C.; Martinez Nocito, F. FAO/WHO scientific update on carbohydrates in human nutrition: Introduction. *Eur. J. Clin. Nutr.* **2007**, *61*, 1–4. [CrossRef] [PubMed]
25. Khan, N.C.; Hoan, P.V. Vietnam recommended dietary allowances 2007. *Asia Pac. J. Clin. Nutr.* **2008**, *17*, 409–415. [PubMed]
26. Food and Nutrition Board, Institute of Medicine of the National Academies. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids*; The National Academies Press: Washington, DC, USA, 2005.
27. Food and Agricultural Organization; World Health Organization; United Nations University. *Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation, Rome, 17–24 October 2001*; Food and Agricultural Organization: Rome, Italy, 2004.
28. Frei, B.; Birlouez-Aragon, I.; Lykkesfeldt, J. Authors' perspective: What is the optimum intake of vitamin C in humans? *Crit. Rev. Food Sci. Nutr.* **2012**, *52*, 815–829. [CrossRef] [PubMed]
29. Miglio, C.; Chiavaro, E.; Visconti, A.; Fogliano, V.; Pellegrini, N. Effects of different cooking methods on nutritional and physicochemical characteristics of selected vegetables. *J. Agric. Food Chem.* **2008**, *56*, 139–147. [CrossRef] [PubMed]
30. Cook, J.D.; Reddy, M.B. Effect of ascorbic acid intake on nonheme-iron absorption from a complete diet. *Am. J. Clin. Nutr.* **2001**, *73*, 93–98. [PubMed]
31. Collings, R.; Harvey, L.J.; Hooper, L.; Hurst, R.; Brown, T.J.; Ansett, J.; King, M.; Fairweather-Tait, S.J. The absorption of iron from whole diets: A systematic review. *Am. J. Clin. Nutr.* **2013**, *98*, 65–81. [CrossRef] [PubMed]
32. Kongkachuichai, R.; Napatthalung, P.; Charoensiri, R. Heme and nonheme iron content of animal products commonly consumed in Thailand. *J. Food Compos. Anal.* **2002**, *15*, 389–398. [CrossRef]
33. Hallberg, L. Bioavailability of dietary iron in man. *Annu. Rev. Nutr.* **1981**, *1*, 123–147. [CrossRef] [PubMed]
34. Hurrell, R.; Egli, I. Iron bioavailability and dietary reference values. *Am. J. Clin. Nutr.* **2010**, *91*, 1461–1467. [CrossRef] [PubMed]
35. Roos, N.; Thorseng, H.; Chamnan, C.; Larsen, T.; Gondolf, U.H.; Bukhave, K.; Thilsted, S.H. Iron content in common Cambodian fish species: Perspectives for dietary iron intake in poor, rural households. *Food Chem.* **2007**, *104*, 1226–1235. [CrossRef]
36. Roos, N.; Wahab, M.A.; Chamnan, C.; Thilsted, S.H. The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. *J. Nutr.* **2007**, *137*, 1106–1109. [PubMed]
37. Laillou, A.; Pfanner, S.; Chan, T.; Chea, C.; Mam, B.; Sambath, P.; Vonthanak, S.; Wieringa, F. Beyond effectiveness—The adversities of implementing a fortification program. A case study on the quality of iron fortification of fish and soy sauce in Cambodia. *Nutrients* **2016**, *8*, 94. [CrossRef] [PubMed]
38. Muthayya, S.; Hall, J.; Bagriansky, J.; Sugimoto, J.; Gundry, D.; Matthias, D.; Prigge, S.; Hindle, P.; Moench-Pfanner, R.; Maberly, G. Rice fortification: An emerging opportunity to contribute to the elimination of vitamin and mineral deficiency worldwide. *Food Nutr. Bull.* **2012**, *33*, 296–307. [CrossRef] [PubMed]
39. De Gier, B.; Campos Ponce, M.; Perignon, M.; Fiorentino, M.; Khov, K.; Chamnan, C.; De Boer, M.R.; Parker, M.E.; Burja, K.; Dijkhuizen, M.A.; et al. Micronutrient-fortified rice can increase hookworm infection risk: A cluster randomized trial. *PLoS ONE* **2016**, *11*, e0145351. [CrossRef] [PubMed]
40. Perignon, M.; Fiorentino, M.; Kuong, K.; Dijkhuizen, M.A.; Burja, K.; Parker, M.; Chamnan, C.; Berger, J.; Wieringa, F.T. Impact of multi-micronutrient fortified rice on hemoglobin, iron and vitamin A status of Cambodian schoolchildren: A double-blind cluster-randomized controlled trial. *Nutrients* **2016**, *8*, 29. [CrossRef] [PubMed]

41. Tanumihardjo, S.A.; Russell, R.M.; Stephensen, C.B.; Gannon, B.M.; Craft, N.E.; Haskell, M.J.; Lietz, G.; Schulze, K.; Raiten, D.J. Biomarkers of nutrition for development (BOND)-vitamin A review. *J. Nutr.* **2016**, *146*, 1816–1848. [CrossRef] [PubMed]
42. Wieringa, F.T.; Dahl, M.; Chamnan, C.; Poirot, E.; Kuong, K.; Sophonneary, P.; Sinuon, M.; Greuffeille, V.; Hong, R.; Berger, J.; et al. The high prevalence of anemia in Cambodian children and women cannot be satisfactorily explained by nutritional deficiencies or hemoglobin disorders. *Nutrients* **2016**, *8*, 348. [CrossRef] [PubMed]
43. Watanabe, F. Vitamin B12 sources and bioavailability. *Exp. Biol. Med.* **2007**, *232*, 1266–1274. [CrossRef] [PubMed]

4. Dietary diversity in Cambodian garment workers: the role of free lunch provision (Paper III)

nutrients

MDPI

Communication

Dietary Diversity in Cambodian Garment Workers: The Role of Free Lunch Provision

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Abstract: The objective of this paper is to compare food consumption by Cambodian garment workers with and without access to a free model lunch provision through a factory-based canteen. Data from an exploratory randomised controlled trial were analysed. In total, 223 female Cambodian garment workers were allocated to an intervention arm (six-month lunch provision) or a control arm. Dietary intake on workdays was assessed by qualitative 24-h recalls at baseline and twice at follow-ups during the period of lunch provision using the Food and Agricultural Organization (FAO) guideline on assessing women's dietary diversity. In total, 158 participants provided complete data on the dietary intake over workdays at all interviews. Lunch provision resulted in a more frequent consumption of dark green leafy vegetables (DGLV), vitamin A-rich fruits, other fruits, and oils and fats during lunch breaks. In contrast, flesh meats, legumes, nuts and seeds, as well as sweets, were eaten at a lower frequency. Except for a higher consumption rate of vitamin A-rich fruits and a lower intake frequency of sweets, lunch provision had a less clear impact on total 24-h intake from different food groups and was not associated with a higher women's dietary diversity score (WDDS). A more gap-oriented design of the lunch sets taking into account underutilised foods and the nutritional status of the workers is recommended.

Keywords: dietary diversity; lunch provision; staff canteen; garment factory; Cambodia; industrial worker

1. Introduction

The setup of staff canteens serving free lunch in Cambodian garment factories has been proposed as a suitable intervention to improve the dietary intake and the nutritional and health status of socially disadvantaged employees [1]. However, there is a lack of insight concerning the true consequences of lunch provision. The vast majority of factories does not have a canteen, with operation costs being the most critical factor [1]. The Lunch Provision in Garment Factories (LUPROGAR) study was a factory-based exploratory randomised controlled trial to assess the effects of a six-month low-price model lunch provision through a canteen during workdays on the nutritional status (anthropometry and micronutrient status) of female garment workers in Cambodia. Prior to this paper, the authors provided detailed information on the participants' nutritional and health status at baseline [2], as well as on the low-price model lunch provision approach within the trial [3]. The objective of the present

survey is to compare the frequency of consumption of food groups (at lunch and in total over 24 h) between study subjects with and without access to the model lunch provision.

2. Materials and Methods

2.1. Study Setting

The LUPROGAR trial was implemented in 2015 at Apsara Garment Co. Ltd., an export-oriented garment factory located in the suburban commune Chom Chau of Phnom Penh, the capital of Cambodia. The majority of the 1300 employees were young unmarried women from low-income rural households. Conditions of employment were assumed to be comparable with overall working conditions in the sector. Apsara Garment Co. Ltd. operated on six workdays per week and was selected purposely since the management showed interest in collaborating in this research.

2.2. Participants

The study population included young non-pregnant nulliparous females employed by Apsara Garment Co. Ltd. The recruitment procedure has been described previously in detail [2]. In brief, signed informed consent forms were obtained from interested workers at lunch breaks and after work (middle of March until the beginning of April 2015), prior to any data collection. Workers who signed the informed consent were invited to the enrolment and baseline assessment (end of April 2015), which included a clinical screening. Background information on baseline sociodemographic characteristics, anthropometry, and haemoglobin and micronutrient status of the enrolled subjects can be found elsewhere [2].

2.3. Randomisation

Enrolled participants were individually allocated in equal shares into an intervention arm (access to six-month free lunch provision through canteen during workdays) and a control arm (equal monetary compensation at the end of the trial). A random variable (a/b) was assigned to each registered subject by making use of the random number generator within SPSS (v.22, IBM Corp., Armonk, NY, USA).

2.4. Lunch Provision

A temporary canteen was installed in a roofed outdoor area at the factory site specifically for this trial [3]. Adequate full lunch sets (consisting of a stir-fried dish, a soup, a side item (cooked rice), and a fruit dessert) were provided in collaboration with Hagar Catering and Facilities Management Ltd., an established Phnom Penh-based canteen service provider. Sets should provide about one-third of the recommended dietary allowance (RDA) for non-pregnant women aged 19–30 years old (total roughly 700 kcal) [4]. Based on these standards, a biweekly menu (including 12 model lunch sets) was outlined in consultation with the caterer [3]. Focus was laid on acceptable Cambodian dishes, using local foods and ensuring variety by providing cereals, various vegetables, animal source foods (meat or fish), and fresh fruits on a daily basis. Lunch provision for the intervention group was carried out by the caterer for six months from beginning of May till end of October 2015. Access to the canteen was voluntary and recorded daily. Additional information on exact costs, components and ingredients, serving sizes, and corresponding nutritive value of single lunch sets can be found elsewhere [3].

2.5. Data Collection

Dietary intake on workdays was assessed at baseline and at two follow-up interviews during the six-month lunch provision period (first follow-up at 2.5 months and second follow-up at 5 months) using the Food and Agricultural Organization (FAO) guideline and questionnaire on recording individual dietary diversity [5]. Subjects were asked to recall all foods and drinks they had consumed in the previous 24 h (always a workday). In the case of composite dishes, respondents were asked in

detail for each individual ingredient, following a list of ingredients that was generated beforehand (including individual ingredients in lunch sets served at the canteen). All foods and drinks mentioned were then categorised into 16 food groups [5]. The food groups covered were noted separately for breakfast, lunch, and dinner, as well as for total 24-h intake. Skipped meals were recorded. Additional questions on home-prepared foods and purchasing at lunch breaks were added to the initial FAO questionnaire. The women's dietary diversity score (WDDS) was calculated with data on total 24-h intake [5].

2.6. Statistical Analysis

The sample size calculation is described in detail in a previous paper [2]. Data from the questionnaires were double-entered using EpiData (v.3.1, EpiData Association, Odense, Denmark) while data management and analyses were executed using SPSS (v.22, IBM Corp.). The evaluation in this survey only included participants with complete data on workday dietary intake at all interviews. Differences between groups were tested using Fisher's exact test in nominal variables and independent Student's *t*-test in the continuous variable WDDS. Inequalities were considered statistically significant at $p < 0.05$.

2.7. Ethical Approval

The trial was conducted according to the guidelines laid down in the Declaration of Helsinki. Approval was obtained from the Institutional Review Board of the Faculty of Medicine at Justus Liebig University, Giessen, Germany (Identifier: 198/14) and the National Ethics Committee for Health Research at the Ministry of Health, Phnom Penh, Cambodia (Identifier: 0363 NECHR). Written informed consent was collected from all participants. The trial was registered at the German Clinical Trials Register (Identifier: DRKS00007666).

3. Results and Discussion

From a total of 267 workers who signed the informed consent, 229 were present at enrolment and 223 were randomly assigned to the control (n = 112) and the intervention group (n = 111) [2]. Baseline sociodemographic data are presented elsewhere [2] and equivalence amongst the groups was given. In total, 172 participants (n = 86 in each arm) completed the overall trial. All dropouts occurred equally distributed in both groups within the first two months. Unexpectedly, a part of the total factory staff, and therefore also women who already signed consents or were enrolled, ceased to work and left the factory during the initial study period. Daily lunch provision had great acceptance among the intervention subjects, who on average visited the canteen on 85% of the intervention days. In total, 158 subjects (n = 80 control and n = 78 intervention) had complete data on dietary intake for the workdays at all interviews (14 subjects did not work at the factory on the previous day at one or more of the assessments).

Table 1 presents details about the dietary intake at lunch breaks by group. Before the study, 14% of participants consumed some types/items of home-prepared foods, whereas the vast majority (96%) purchased food and drinks in front of the factory gates. Foods most commonly consumed at lunch were cereals (100%, solely rice), flesh meats (72%), other vegetables (60%), sweets (54%), oils and fats (53%), fish and seafood (49%), dark green leafy vegetables (DGLV) (47%), and other fruits (44%). The frequency of consumption of vitamin A-rich fruits (1%), milk and milk products (1%), organ meat (2%), white roots and tubers (4%), and eggs (7%), was low. On average, subjects' lunch meals at baseline were composed of 6.5 (standard deviation (SD) = 1.8) food groups and represented the most diverse meal as compared to breakfast and dinner (food group intake at breakfast/dinner not shown). There were no baseline differences between groups in variables of dietary intake at lunch breaks.

The frequency of workers with home-prepared food for lunch breaks in the intervention group expectedly dropped to 0% at follow-ups. Since access to free lunch provision resulted in saving time and effort on food preparation it might also decrease the risk of lack of food safety as lunch boxes are usually stored without cooling on factory grounds [1]. Significantly fewer intervention participants

reported purchasing food/drinks at follow-up interviews. Still, the proportion remained surprisingly high, although the lunch provision also included unlimited access to drinking water at the canteen. Intervention subjects mostly reported additional purchase of beverages and sweets after having visited the canteen.

At both dietary re-assessments, the lunch intake by intervention subjects was significantly higher for DGLV, vitamin A-rich fruits, other fruits, and oils and fats. On the other hand, access to lunch provision was also significantly associated with a lower rate in consumption of flesh meats, legumes, nuts and seeds, sweets (all at both follow-ups), and eggs (only at 5 months).

The served lunch sets included various vegetables (often DGLV), fruits (including vitamin A-rich fruits), as well as a small amount of cooking oil [3]. The lower consumption rate of flesh meats at lunch can be attributed to the regular serving of fish portions in model lunch sets [3]. Only a few dishes served at the canteen included legumes and none contained nuts. Eggs were only served once within the biweekly model menu [3]. Control participants often reported lunch intake of soy bean products and/or groundnuts, as total participants did at baseline. As sweets were not provided at the canteen, any consumption of sweets in intervention women rested on additional purchase outside the factory. Nevertheless, a lower intake of free sugar among workers is regarded as beneficial [6]. Given the overall low rate in organ meats consumption at lunch breaks and the low total iron content in the lunch sets [3], future concepts should incorporate more of these haem-iron rich foods [7].

Table 2 and Figure 1 present the data on total 24-h dietary intake and dietary diversity scores during workdays by group. Initially, there were no differences between the groups. At baseline, 10% of subjects skipped breakfast. Skipping of breakfast in intervention participants increased to 21% at 2.5 months, however, no significant difference in skipping breakfast between groups was observed at both follow-up interviews. Skipping of meals in garment workers with access to a staff canteen should be closely monitored, as it might counteract the expected benefits from lunch provision. With increasing rates of women skipping breakfast, lunch programmes for workers might need to consider additional meal/snack provision in the morning.

Overall, baseline 24-h intake from the different food groups was characterised by consumption of cereals (100%, mainly rice), oils and fats (89%), flesh meats (89%), other vegetables (80%), fish and seafood (75%), DGLV (74%), sweets (67%), other fruits (55%), vitamin A-rich vegetables and tubers (42%), and legumes, nuts and seeds (34%). The mean WDDS at baseline was 4.7 (SD = 1.1), representing an "adequate" dietary diversity on average [8]. Although the consumption of iron-rich foods (flesh meats and fish) was common, the prevalence of low iron status at baseline was high in enrolled subjects [2]. The quantities of these foods might have not been sufficient to meet the RDA for iron as reported for Cambodian women in rural areas [9].

The evaluation of the 24-h food group intake at follow-up interviews showed a differentiated impact of lunch provision. On the one hand, the intake of vitamin A-rich fruits was significantly higher and the consumption of sweets was significantly lower in intervention subjects at both re-assessments. On the other hand, a significantly higher rate in intake of other fruits, vitamin A-rich vegetables and tubers, and DGLV, as well as a significantly lower intake of legumes, nuts and seeds, and eggs, was noted only for one of the two follow-up interviews. Different to the intake from food groups during lunch breaks, no differences were observed between the intervention and the control group for the 24-h dietary intake of flesh meats.

Although the mean WDDS among the intervention group increased from 4.6 (SD = 1.1) at baseline to 5.4 (SD = 1.0) at both follow-ups, no significant differences in WDDS between groups could be observed, which is assumed to be in line with the lunch provisions' overall little impact on 24-h food group intake. The mean WDDS in control subjects was 5.4 (SD = 1.2) and 5.1 (SD = 1.3) at 2.5 and 5 months, respectively.

Table 1. Home-prepared food, purchasing, and food group intake at lunch breaks at baseline and follow-up interviews in female Cambodian garment workers without (control) and with access to the free model lunch provision through a canteen (intervention). [1]

	Baseline (End of April 2015)			At 2.5 Months (Middle of July 2015)			At 5 Months (Beginning of October 2015)		
	Control (n = 80)	Intervention (n = 78)		Control (n = 80)	Intervention (n = 78) [2]		Control (n = 80)	Intervention (n = 78) [3]	
Variables	n (%)	n (%)	p	n (%)	n (%)	p	n (%)	n (%)	p
Home-prepared food for lunch break	11 (14)	11 (14)	ns	15 (19)	0 (0)	<0.001	5 (6)	0 (0)	0.059
Purchased food/drinks at lunch break	76 (95)	76 (97)	ns	77 (96)	43 (55)	<0.001	77 (96)	46 (59)	<0.001
Food group intake at lunch break									
Cereals	80 (100)	78 (100)	-	80 (100)	78 (100)	-	80 (100)	78 (100)	-
Spices, condiments, and beverages	79 (99)	77 (99)	ns	79 (99)	78 (100)	ns	79 (99)	78 (100)	ns
Flesh meats	58 (73)	55 (71)	ns	57 (71)	39 (50)	0.009	68 (85)	43 (55)	<0.001
Other vegetables	52 (65)	43 (55)	ns	52 (65)	54 (69)	ns	56 (70)	59 (76)	ns
Sweets	44 (55)	42 (54)	ns	57 (71)	27 (35)	<0.001	54 (68)	29 (37)	<0.001
Oils and fats	47 (59)	36 (46)	ns	52 (65)	73 (94)	<0.001	58 (73)	74 (95)	<0.001
Fish and seafood	43 (54)	35 (45)	ns	36 (45)	42 (54)	ns	37 (46)	36 (46)	ns
Dark green leafy vegetables	36 (45)	38 (49)	ns	41 (51)	62 (80)	<0.001	38 (48)	58 (74)	0.001
Other fruits	37 (46)	33 (42)	ns	49 (61)	70 (90)	<0.001	48 (60)	62 (80)	0.009
Legumes, nuts and seeds	22 (28)	23 (30)	ns	35 (44)	13 (17)	<0.001	29 (36)	16 (21)	0.035
Vitamin A-rich vegetables and tubers	19 (24)	22 (28)	ns	27 (34)	31 (40)	ns	28 (35)	35 (45)	ns
Eggs	8 (10)	3 (4)	ns	11 (14)	13 (17)	ns	13 (16)	2 (3)	0.005
White roots and tubers	5 (6)	1 (1)	ns	10 (13)	17 (22)	ns	10 (13)	14 (18)	ns
Organ meat	3 (4)	0 (0)	ns	1 (1)	0 (0)	ns	2 (3)	2 (3)	ns
Vitamin A-rich fruits	1 (1)	0 (0)	ns	2 (3)	10 (13)	0.017	1 (1)	12 (15)	0.001
Milk and milk products	1 (1)	0 (0)	ns	8 (10)	3 (4)	ns	9 (11)	3 (4)	ns

[1] Intervention group had access to free model lunch provision on workdays through a canteen for six months (beginning of May until the end of October 2015) [3]. Evaluation in participants with complete data on workday dietary intake at all interviews. p-values from group comparisons using Fisher's exact test; [2] n = 72 visited the canteen; [3] n = 71 visited the canteen; ns: not significant.

Table 2. Skipped meals and total 24-h food group intake on workdays at baseline and follow-up interviews in female Cambodian garment workers without (control) and with access to the free model lunch provision through a canteen (intervention). [1]

	Baseline (End of April 2015)			At 2.5 Months (Middle of July 2015)			At 5 Months (Beginning of October 2015)		
	Control (n = 80)	Intervention (n = 78)		Control (n = 80)	Intervention (n = 78) [2]		Control (n = 80)	Intervention (n = 78) [3]	
Variables	n (%)	n (%)	p	n (%)	n (%)	p	n (%)	n (%)	p
Skipped meals									
Breakfast	9 (11)	7 (9)	ns	10 (13)	16 (21)	ns	12 (15)	11 (14)	ns
Lunch	0 (0)	0 (0)	-	0 (0)	0 (0)	-	0 (0)	0 (0)	-
Dinner	1 (1)	1 (1)	ns	0 (0)	2 (3)	ns	1 (1)	0 (0)	ns
Total 24-h food group intake									
Cereals	80 (100)	78 (100)	-	80 (100)	78 (100)	-	80 (100)	78 (100)	-
Spices, condiments and beverages	80 (100)	78 (100)	-	80 (100)	78 (100)	-	80 (100)	78 (100)	-
Oils and fats	75 (94)	66 (85)	ns	77 (96)	78 (100)	ns	75 (94)	78 (100)	ns
Flesh meats	73 (91)	68 (87)	ns	77 (96)	71 (91)	ns	75 (94)	72 (92)	ns
Other vegetables	69 (86)	58 (74)	ns	70 (88)	67 (86)	ns	69 (86)	70 (90)	ns
Fish and seafood	61 (76)	57 (73)	ns	61 (76)	59 (76)	ns	62 (78)	57 (73)	ns
Dark green leafy vegetables	60 (75)	57 (73)	ns	64 (80)	69 (89)	ns	49 (61)	68 (87)	<0.001
Sweets	53 (66)	53 (68)	ns	62 (78)	43 (55)	0.004	63 (79)	46 (59)	0.010
Other fruits	46 (58)	41 (53)	ns	55 (69)	71 (91)	0.001	58 (73)	66 (85)	ns
Vitamin A-rich vegetables and tubers	33 (41)	34 (44)	ns	39 (49)	43 (55)	ns	33 (41)	46 (62)	0.012
Legumes, nuts and seeds	27 (34)	26 (33)	ns	43 (54)	23 (30)	0.002	32 (40)	27 (35)	ns
Eggs	19 (24)	16 (21)	ns	30 (38)	35 (45)	ns	35 (44)	20 (26)	0.020
White roots and tubers	7 (9)	2 (3)	ns	13 (16)	18 (23)	ns	13 (16)	14 (18)	ns
Milk and milk products	4 (5)	4 (5)	ns	16 (20)	12 (15)	ns	19 (24)	18 (23)	ns
Organ meat	5 (6)	2 (3)	ns	7 (9)	7 (9)	ns	4 (5)	7 (9)	ns
Vitamin A-rich fruits	2 (3)	3 (4)	ns	2 (3)	11 (14)	0.009	2 (3)	14 (18)	0.001

[1] Intervention group had access to free model lunch provision on workdays through a canteen for six months (beginning of May until the end of October 2015) [3]. Evaluation in participants with complete data on workday dietary intake at all interviews. p-values from group comparisons using Fisher's exact test.; [2] n = 72 visited the canteen; [3] n = 71 visited the canteen; ns: not significant.

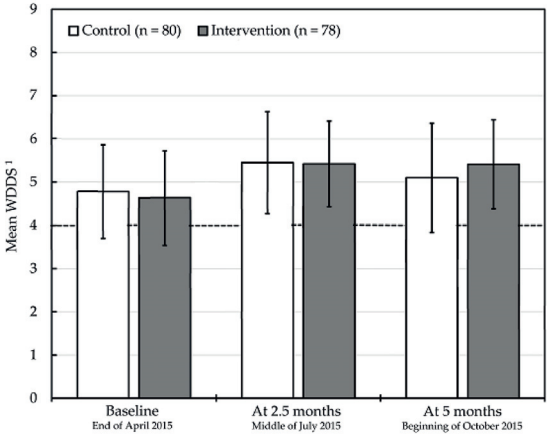

Figure 1. Mean women's dietary diversity score (WDDS) at baseline and follow-up interviews in female Cambodian garment workers without (control) and with access to the six-month free model lunch provision through a canteen (intervention). Evaluation in participants with complete data on workday dietary intake at all interviews. Lines within bars illustrate the standard deviations. The dashed line indicates a cut-off for "inadequate" (WDDS < 4) and "adequate" (WDDS $\geq$ 4) dietary diversity [8]. Group comparisons using Student's independent *t*-test showed no significant differences. [1] Aggregated continuous indicator (0–9), based on total 24-h consumption of starchy staples (cereals and/or white roots and tubers); dark green leafy vegetables; vitamin A-rich fruits and vegetables (vitamin A-rich vegetables and tubers and/or vitamin A-rich fruits); other fruits and vegetables (other fruits and/or other vegetables); organ meat; meat and fish (flesh meats and/or fish and seafood); eggs; legumes, nuts and seeds; and milk and milk products [5].

Limitations of the Study

The trial's model lunch provision was not specifically designed for improving the intake of specific foods nor the overall dietary diversity. Moreover, the enrolled women generally showed a relatively diverse total dietary intake, given their mean WDDS of 4.7 at baseline. Furthermore, as the calculation of the sample size for the LUPROGAR trial was based on different outcomes [2], it is not fully appropriate for the evaluation of frequencies of food group consumption. Given the relatively small sample size within this trial, inequalities between the control and the intervention group had to be marked to reach statistical significance. At last, no correction for multiple comparisons was conducted, which is in line with recommendations for exploratory studies [10].

4. Conclusions

LUPROGAR's low-price model lunch provision for Cambodian garment workers resulted in a more frequent consumption of DGLV, vitamin A-rich fruits, other fruits, and oils and fats during lunch. In contrast, it was likewise associated with a lower intake frequency of flesh meats, legumes, nuts and seeds, and sweets. Future model lunch sets for this group of women should incorporate some organ meats to increase the provision of iron. Beside a higher consumption rate of vitamin A-rich fruits and a lower intake frequency of sweets, lunch provision had a less clear impact on total 24-h intake from different food groups and was not associated with a higher WDDS. A more gap-oriented design of the lunch sets taking into account underutilised foods and the nutritional status of the workers is

recommended for increasing their WDDS. Finally, skipping of meals in workers with access to a staff canteen should be closely monitored in order to avoid unfavourable dietary changes.

Author Contributions: J.M. and M.B.K. designed the LUPROGAR study; J.M. coordinated the implementation and data collection; F.T.W. and C.C. supervised the data collection; J.M. and E.C.K. conducted the data analysis; J.M. and E.C.K. wrote the manuscript; and all authors contributed to the review of the manuscript and approved its final version.

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References

1. BDLINK; HRINC. *Study on the Perceptions of Garment Factory Owners on Nutrition and the Feasibility for Pursuing Canteen Services in the Garment Sector in Cambodia*; International Labour Organization: Phnom Penh, Cambodia, 2012. Available online: https://data.opendevelopmentmekong.net/dataset/b737251d-6570-4171-aa66-8580becd701e/resource/e2612dd0-2335-4a7e-87cd-1ebff65702d5/download/perceptions-on-nutrition-and-canteens-in-the-garment-industry.pdf (accessed on 28 February 2018).
2. Makurat, J.; Friedrich, H.; Kuong, K.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Nutritional and micronutrient status of female workers in a garment factory in Cambodia. *Nutrients* **2016**, *8*, 694. [CrossRef] [PubMed]
3. Makurat, J.; Pillai, A.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Estimated nutritive value of low-price model lunch sets provided to garment workers in Cambodia. *Nutrients* **2017**, *9*, 782. [CrossRef] [PubMed]
4. Barba, C.V.; Cabrera, M.I. Recommended dietary allowances harmonization in Southeast Asia. *Asia Pac. J. Clin. Nutr.* **2008**, *17*, 405–408. [PubMed]
5. Food and Agricultural Organization. *Guidelines for Measuring Household and Individual Dietary Diversity*; Food and Agricultural Organization: Rome, Italy, 2011.
6. World Health Organization. *Guideline: Sugars Intake for Adults and Children*; World Health Organization: Geneva, Switzerland, 2015.
7. Kongkachuichai, R.; Napatthalung, P.; Charoensiri, R. Heme and nonheme iron content of animal products commonly consumed in Thailand. *J. Food Compos. Anal.* **2002**, *15*, 389–398. [CrossRef]
8. Zerfu, T.A.; Umeta, M.; Baye, K. Dietary diversity during pregnancy is associated with reduced risk of maternal anemia, preterm delivery, and low birth weight in a prospective cohort study in rural Ethiopia. *Am. J. Clin. Nutr.* **2016**, *103*, 1482–1488. [CrossRef] [PubMed]
9. Wallace, L.J.; Summerlee, A.J.; Dewey, C.E.; Hak, C.; Hall, A.; Charles, C.V. Women's nutrient intakes and food-related knowledge in rural Kandal province, Cambodia. *Asia Pac. J. Clin. Nutr.* **2014**, *23*, 263–271. [PubMed]
10. Bender, R.; Lange, S. Adjusting for multiple testing—When and how? *J. Clin. Epidemiol.* **2001**, *54*, 343–349. [CrossRef]

5. Impact of lunch provision on anthropometry, hemoglobin, and micronutrient status of Cambodian garment workers: exploratory randomized controlled trial (Paper IV)

Impact of lunch provision on anthropometry, hemoglobin, and micronutrient status of Cambodian garment workers: exploratory randomized controlled trial

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Abstract

Background: Lunch provision is expected to improve the nutritional status of Cambodian garment workers. The objective of this study is to evaluate the effects of a model lunch provision through a canteen on anthropometry, hemoglobin, and micronutrient status in garment workers in Cambodia.

Methods: This exploratory randomized controlled trial was implemented at a garment factory in Phnom Penh, Cambodia. Female workers (nulliparous, non-pregnant) were recruited and randomly allocated into an intervention arm (workday's lunch provision) and a control arm. Served lunch sets (~700 kcal on average) included diverse local dishes. Anthropometry (body mass index, weight, triceps skinfold thickness, and mid-upper arm muscle circumference), as well as hemoglobin, serum ferritin and soluble transferrin receptor, serum retinol binding protein, and serum folate concentrations were assessed at baseline and after five months of lunch provision.

Results: 223 women were recruited (n=112 control and n=111 intervention). 172 (n=86 in each arm) completed the study. Baseline prevalence of underweight, anemia, depleted iron stores, and marginal iron stores, were 31%, 24%, 21%, and 50%, respectively. Subjects were not affected by frank vitamin A or folate deficiency, whereas 30% showed a marginal folate status. Overall, mean changes in anthropometric variables, hemoglobin, and retinol binding protein were marginal and not significant among intervention subjects. Mean folate concentration increased by +1.1 ng/mL (-0.02, 2.2) (p=0.054), representing a marginally significant positive effect. On the other hand, mean ferritin decreased by -6.6 µg/L (-11.9, -1.3) (p=0.015). Subgroup analysis prompts that effects are differently pronounced according to the baseline status of workers.

Conclusions: Findings indicate that model lunch sets provided a beneficial amount of dietary folate, but need to be revisited for iron content and/or iron bioavailability. Distinct positive effects on anthropometry, hemoglobin, and micronutrient status can solely be expected in malnourished individuals. The authors

suggest that similar larger trials, which include sets adapted to the concrete needs of workers affected by underweight, anemia and/or definite micronutrient deficiencies, should be performed.

Trial registration: The trial was registered at the German Clinical Trials Register (9 January 2015, Identifier: DRKS00007666).

Keywords

Lunch provision, Staff canteen, Garment factory, Cambodia, Randomized controlled trial, Malnutrition, Underweight, Anemia, Micronutrient deficiency, Industrial worker

Background

More than 600 export-oriented garment factories operate in Cambodia, playing an important part in the country's economy [1]. Located in and around the suburbs of Phnom Penh, the capital of Cambodia, they are usually owned by foreign investors [1–3]. Factories mostly implement low value-added activities and depend on cheap labor [2,3]. Almost 90% of their 600,000 employees are female, generally young women who migrate from disadvantaged low-income rural households [4–6]. The 2017 minimum wage for Cambodian garment workers amounted to 153 USD/month, which was distinctly lower in previous years [1]. Workers heavily rely on bonuses and overtime work [5,7,8]. A large share of the finances made while working in the factories, often more than 50% of the total salary, is budgeted to support family members [5–8].

Considering the low disposable funds among workers, concerns about their nutritional situation have raised over the past years [7,8]. Socio-economic surveys concluded that an appropriate diet in terms of quantity and quality is likely to be out of reach, given the thrifty sum spent by workers on food (~1.5 USD/day, normally at food stalls close to factories) [5,7,8]. Saving measures also involve skipping of meals [5,8]. Malnutrition among workers has become a sensitive topic in media, especially as it has been linked to the faintings frequently reported from the factories [5]. However, sound data regarding the dietary intake of Cambodian garment workers are missing. Based on a small cross-sectional survey, NGOs reported a

prevalence of 36% underweight among female workers [5]. On the other hand, a study conducted by the ILO in several factories found 14% of workers to be underweight and 45% to be anemic [9]. Finally, the authors reported on 31% underweight, 27% anemia, and a high prevalence of poor iron status (data from the present factory-based study) [6].

Malnutrition of women in reproductive age (with respect to underweight, anemia, and micronutrient deficiencies) is associated with impaired cognition, reduced work capacity, and lowered resistance to infections [10–12]. During gestation, it is linked to increased maternal morbidity and mortality, premature delivery, low birth weight, and increased fetal and neonatal deaths [10–12]. Anemia of nutritional origin is caused by diets that lack sufficient amounts of essential hematopoietic micronutrients, such as iron, vitamin A (VitA), vitamin B12 (VitB12), and/or folate [10,13]. Non-nutritional factors are especially genetically determined hemoglobinopathies, menstrual blood loss, and parasite infestation (e.g. in malaria and helminths) [10,14,15].

The establishment of canteens serving lunch in Cambodian garment factories has been proposed as an adequate intervention to improve the nutritional situation of workers, to reduce morbidity and absenteeism, and thereby to increase productivity [16]. Nevertheless, convincing trials that verify these hypotheses are rare. The ILO reported that meal provision showed positive effects on dietary diversity, on food security, and on lowering the percentage of employees who have taken loans for food purchases [9]. Still, the vast majority of factories does not hold a canteen, with the operation costs being the most critical factor for factory owners [16].

Despite the implementation of a first on-topic survey by the ILO [9], detailed insights are missing concerning the consequences of lunch provision on the nutritional and health status of Cambodian garment workers. Yet, this knowledge is essential to empower stakeholders along the Cambodian garment sector to make informed choices on the setup and operation of staff canteens. The current paper reports on the main outcomes of the LUPROGAR study (Lunch Provision in Garment Factories), a factory-based exploratory randomized controlled trial, whose primary objective is to determine the impact of a low-price model lunch

provision through a local canteen during workdays on anthropometry, as well as on the hemoglobin (Hb) and micronutrient status of female garment workers in Cambodia. Prior to this essay, the authors provided detailed information on the participants' nutritional and health status at baseline [6], as well as on the low-price model lunch provision approach within this trial [17].

Methods

Study design and setting

LUPROGAR was a factory-based exploratory randomized controlled trial (two-group, 1:1 ratio, parallel), planned for a six-month period. The study was implemented during 2015 at Apsara Garment Co. Ltd., an export-oriented garment factory located in the suburban commune Chom Chau in Phnom Penh, about 10 km west of the city center. The majority of the 1,300 employees were young unmarried women from low-income rural households. Conditions of employment were assumed to be comparable with overall working conditions in the sector. Apsara Garment Co. Ltd. operated on six workdays per week and was selected purposely since the management showed interest in collaborating in this research. One study coordinator and one research assistant conducted the prior staff trainings and supervised overall study implementation and data collection. The entire assessment team consisted of two local nurses and four local project assistants (enumerators).

Participants

The study population included non-pregnant nulliparous women employed by Apsara Garment Co. Ltd.. To be eligible, women had to meet the inclusion criteria and provide written informed consent before enrollment. Inclusion criteria for the trial were: being nulliparous, non-pregnant, healthy, and <31 years at the date of enrollment. The exclusion criteria were: acute or chronic disease requiring treatment and/or medication, handicaps interfering with nutritional and/or health status, Hb concentration <7.0 g/dL, clinical signs of VitA- or iodine deficiency, and employment as supervisor/superintendent. Workers excluded from participation due to health issues were referred for treatment.

Beginning of March 2015, the factory management, superintendents, and union representatives were informed in detail about the objectives and procedure of the LUPROGAR trial. Subsequently, the study was announced and explained during a meeting to all factory employees. Written informed consents were obtained from interested workers at an information desk at lunch breaks and at the end of working days by trained assistants prior to any data collection (mid of March till beginning of April 2015). Workers who signed the informed consent were invited to the enrollment and baseline assessment, which took place in a separate room during working hours and included a clinical screening performed by trained nurses (end of April 2015).

Randomization

Enrolled participants were individually allocated (carried out by research assistant) in equal shares into an intervention arm (access to six-month lunch provision through local canteen during workdays) and a control arm (equal monetary compensation at the end of the trial). Simple randomization to groups was implemented through the distinct attribution of a bivariate random variable (a/b) for each registered subject by making use of the random number generator within SPSS (v.22.0.0.1, IBM Corp., USA) (prepared by study coordinator).

Intervention

A temporary canteen was installed in a roofed outdoor area at the factory site [17]. Apsara Garment Co. Ltd. had never operated a staff canteen before. Within the LUPROGAR trial, it was envisaged to serve adequate full lunch sets (consisting of a stir-fried dish, a soup, a side item (cooked rice), and a fruit dessert) at reasonable costs (~1 USD/person/day) in collaboration with Hagar Catering and Facilities Management Ltd., an established Phnom Penh-based canteen service provider. Sets should provide about one third of the recommended dietary allowance (RDA) for non-pregnant women aged 19-30 years old (total ~700 kcal) [18]. Based on these standards, a biweekly menu (of twelve model lunch sets) was outlined in consultation with the caterer [17]. Focus was laid on accepted Cambodian dishes, using local foods and ensuring variety

by providing cereals, various vegetables, animal source foods (meat or fish), and fresh fruits on a daily basis.

Following the enrollment and baseline assessment at the end of April 2015, daily free lunch provision on workdays for the intervention group was carried out by the caterer for six months from beginning of May until end of October 2015. Dishes were prepared according to consistent recipes at a professional kitchen located in Phnom Penh's city center and delivered within 1 hour. Stir-fried and soup dishes were reheated just before serving and the canteen staff was instructed to serve constant portion sizes. At the canteen, participants had free access to drinking water and locally used condiments (non-fortified soy/fish sauce and fresh red chili). After one month, the initial menu was slightly adjusted according to preferences expressed by workers via a short preference questionnaire. Access to the canteen was voluntary and recorded daily by an assistant. Table 1 presents the estimated nutritive value of the lunch sets. Further information on exact costs, components and ingredients, serving sizes, and corresponding nutritive value of single lunch sets can be found elsewhere [17].

Table 1. Estimated nutritive value of the low-price model lunch sets provided to female garment workers at a factory in Phnom Penh, Cambodia.[1]

Nutritive value[2]	Mean	Min.	Max.
Energy, kcal (% of RDA)	697 (33)	591 (28)	793 (38)
Carbohydrates, g (% of RDA)	107 (37)	100 (34)	123 (42)
Protein, g (% of RDA)	23 (46)	16 (32)	30 (60)
Fat, g (% of RDA)	18 (34)	12 (23)	24 (45)
Dietary fiber, g (% of AI)	8 (32)	6 (24)	12 (48)
Vitamin C, mg (% of RDA)	111 (159)	24 (34)	212 (303)
Iron, mg (% of RDA)	6 (20)	4 (14)	12 (41)
Vitamin A, µg RAE (% of RDA)	331 (66)	61 (12)	799 (160)
Folate, µg (% of RDA)	175 (44)	29 (7)	477 (120)
Vitamin B12, µg (% of RDA)	0.7 (29)	0.2 (8)	1.5 (63)

[1]Among twelve various lunch sets (composed of stir-fry, soup, side item (cooked rice), and fruit dessert) provided over a biweekly rotating cycle (one set per day, at six workdays per week). Data from a preceding publication including detailed information on the biweekly menu, costs, ingredients, serving sizes, and estimated individual nutritive values [17]

[2]Following recommendations for non-pregnant women aged 19-30 years old from various sources: energy, protein (adjusted for 80% protein quality), vitamin C, iron (adjusted for 10% bioavailability), vitamin A, and folate [18]; carbohydrates [19]; fat and vitamin B12 [20]; and dietary fiber [21]

Min.: Minimum; Max.: Maximum; kcal: Kilocalories; RDA: Recommended dietary allowance; AI: Adequate intake; RAE: Retinol activity equivalent

Data collection

Trained assistants applied a semi-structured questionnaire at baseline, collecting data on background information and on the socio-economic status of study participants and their respective households. Trained nurses administered a semi-structured health questionnaire, collecting data on present intake of medications, as well as on illness history and sick leave within the 14 days preceding the interview (baseline and follow-up). Both questionnaires were similar to the Cambodian Demographic Health Survey 2014 [22] and were pre-tested under field conditions.

Weight (kg), height (cm), triceps skinfold thickness (TSF, mm), and mid-upper arm circumference (MUAC, cm) of participants were assessed by two trained assistants following CDC guidelines [23] (baseline and follow-up). All devices and measurement procedures were pre-tested under field conditions. Weight was measured without shoes in light clothing to the nearest 0.1 kg, using an electronic UNISCALE scale (UNICEF supply, SECA GmbH, Germany). Height was measured to the nearest 0.1 cm, using a SECA 213 stadiometer (SECA GmbH, Germany). TSF was measured to the nearest 0.2 mm, using a Tanner/Whitehouse caliper (Holtain Ltd., UK). MUAC was measured to the nearest 0.1 cm, using a MUAC measuring tape for adults supplied by UNICEF/WFP. In the TSF/MUAC assessment, the midpoint of the upper arm was determined by using a non-stretchable fiberglass measuring tape. All measurements were taken twice and the mean was used for further analysis. The maximum tolerated differences were 0.1 kg for weight, 0.7 cm for height, 0.2 mm for TSF, and 0.5 cm for MUAC, otherwise the measurement was repeated. Body mass index (BMI, kg/m²) was calculated and subjects were classified using defined cut-off points [23]: severe underweight (BMI <16.0 kg/m^2), moderate underweight (BMI ≥16.0 and <17.0 kg/m^2), mild underweight (BMI ≥17.0 and <18.5 kg/m^2), normal weight (BMI ≥18.5 and <25.0 kg/m^2), and overweight (BMI ≥25.0 and <30.0 kg/m^2). Within normal weight subjects, a BMI between 18.5 and 20.0 kg/m² was also designated as “low-normal BMI” [24]. Mid-upper arm muscle circumference (MUAMC, cm) was calculated using the following equation [25]:

$$MUAMC = MUAC - (\pi \times TSF)$$

Samples of 5 mL non-fasting venous blood (venipuncture at left or right arm) were taken by trained nurses in a separate private area (baseline and follow-up). Immediately after blood was collected, blood drops were put on a hydrophobic glass slide for subsequent twofold blood Hb measurement (g/dL) using a HemoCue Hb 301 photometer (HemoCue AB, Sweden). The mean was used in further analysis. Blood left in the syringe was filled into a serum vacutainer with clot activator (Becton Dickinson, USA), kept at room temperature for a minimum duration of 1 hour to allow for blood clotting, and afterwards kept chilled at 4 °C. Serum was then separated within 3 hours by centrifugation (2700 rpm, calculated equivalent at 1300×g, 10 min), aliquoted into capped Eppendorf tubes, and again kept chilled at 4 °C. The samples were then transported in a cool box containing ice packs to the Department of Fisheries Post-Harvest Technologies and Quality Control (Phnom Penh, Cambodia) and kept frozen at -25 °C until further processing.

Subsamples for the determination of VitB12 concentration were transported in a cool box containing ice packs to the Pasteur Institute Cambodia (Phnom Penh, Cambodia). Serum VitB12 (pmol/L) was measured by electrochemiluminescence, using a COBAS e 411 immunoassay analyzer (Roche Diagnostics, Switzerland) with kits and control samples provided by the manufacturer. When analyzing follow-up subsamples, VitB12 results of controls and samples unexpectedly fell out of the certified ranges. Therefore, only baseline results on VitB12 are shown here.

Remaining serum aliquots were shipped on dry ice to the Institute of Nutritional Sciences at the Justus Liebig University Giessen (Germany) and stored at -25 °C until they were transported in a cool box containing ice packs to the VitMin laboratory (Willstaett, Germany) for determination of ferritin (FER, µg/L), soluble transferrin receptor (sTfR, mg/L), retinol-binding protein (RBP, µmol/L), C-reactive protein (CRP, mg/L), α1-acid-glycoprotein (AGP, g/L), and folate concentrations (ng/mL). FER, RBP, sTfR, CRP, and AGP were determined by a sandwich enzyme-linked immunosorbent assay (ELISA) technique [26]. Serum folate was measured via a microbiological assay by using chloramphenicol-resistant *Lactobacillus rhamnosus* [27]. Both methods used pooled samples for quality control and certified samples (CDC, USA and Bio-Rad, USA) to establish calibration curves for each indicator. All values represent the mean of an

independent double measurement. For folate, the maximum tolerated difference between duplicate measurements was +/- 40%, otherwise the result was not included in further analysis.

Anemia was defined as low Hb (<12.0 g/dL), classified into mild (Hb ≥11.0 and <12.0 g/dL), moderate (Hb ≥8.0 and <11.0 g/dL), and severe (Hb <8.0 g/dL) [10]. Subclinical inflammation was defined as increased CRP (>5 mg/L) and/or increased AGP concentrations (>1 g/L), and categorized into three stages: incubation (high CRP and normal AGP), early convalescence (both CRP and AGP elevated), and late convalescence (high AGP only) [28]. FER concentration was adjusted for inflammation by correction factors for each inflammation stage [28]. Iron deficiency was defined by depleted iron stores (adjusted serum FER <15 µg/L) [10], marginal iron stores by adjusted serum FER ≥15 and <50 µg/L [29], tissue iron deficiency by high serum sTfR (>8.3 mg/L) [30], and iron deficiency anemia by Hb <12.0 g/dL and simultaneous adjusted serum FER <15 µg/L [10]. Serum RBP concentrations were used as a surrogate measure for circulating retinol to evaluate VitA status [31]. RBP values were likewise adjusted for the presence of inflammation by correction factors for each stage of inflammation [32]. VitA deficiency was defined by adjusted serum RBP <0.70 µmol/L and marginal VitA deficiency by adjusted serum RBP values ≥0.70 and <1.05 µmol/L [31,33]. Folate deficiency was defined by serum folate <3 ng/mL and marginal deficiency by serum folate ≥3 and <6 ng/mL [34]. VitB12 deficiency was defined as serum VitB12 <148 pmol/L and a marginal VitB12 deficiency as serum VitB12 ≥148 and <222 pmol/L [35].

Outcomes

Given the exploratory trial design, the outcomes were planned as changes in BMI, weight, TSF, and MUAMC (as anthropometric variables), as well as changes in Hb and serum FER, sTfR, RBP, folate, and VitB12 concentrations (as Hb and micronutrient status) of participants at follow-up (planned at six months).

Sample size

The study used an explorative approach to estimate an appropriate sample size, since both data on the nutritional status of Cambodian garment workers, and exemplary data on the effects of lunch provision in

this context were largely missing at time of trial implementation. Calculations were carried out using G*Power (v.3.1.9.2, University of Kiel, Germany). Assuming a two-tailed 5% level of significance (alpha=0.05) and a statistical power of 80% (beta=0.20) to detect a small to medium standardized effect size of 0.35 (Cohen's *d*) between both arms [36], 130 subjects in each group were required. To allow for about 20% loss to follow up, it was initially aimed at recruiting a total of 330 participants (165 subjects in each arm).

Statistical analysis

Data of questionnaires and anthropometry sheets were double-entered by trained assistants using EpiData (v.3.1, EpiData Association, Denmark). Overall data management and statistical analyses were executed using SPSS (v.22.0.0.1, IBM Corp., USA). Evaluation only included participants who completed the follow-up, regardless of the actual individual adherence of intervention subjects to daily eating lunch at the staff canteen. Detailed baseline findings among all originally enrolled subjects can be found in a previously published paper [6].

A wealth index was computed to assess the socio-economic status of subjects' households using principal component analysis [37]. The index was based on the following variables: number of rooms per household, people per room, main place of cooking, main type of fuel, main material of the floor, and ownership of a bank account, latrine, electricity, and several household assets (radio, television, non-mobile telephone, wardrobe, sewing machine, DVD player, generator, watch, motorcycle, motorcycle cart, car, and boat). Baseline characteristics of the groups were summarized by using descriptive statistics.

In the primary analysis, a general linear model with adjustments for baseline values (covariates) was used to calculate marginal means per group with 95% CIs for each outcome variable at follow-up, as well as to estimate the intervention effects as marginal mean differences with 95% CIs and corresponding effect sizes (Cohen's *d*). The significance was set at 5% (*p*-value <0.05).

In a secondary analysis, the same model was used to compute marginal mean changes with 95% CIs per group for each outcome variable within following subsets (based on the assumption that changes differ according to baseline status): for anthropometric variables, subgroups were underweight (BMI <18.5 kg/m²), low-normal BMI (BMI ≥18.5 and <20.0 kg/m²), and BMI ≥20.0 kg/m² at baseline; for Hb, subgroups were moderate anemia (Hb ≥8.0 and <11.0 g/dL), mild anemia (Hb ≥11.0 and <12.0 g/dL), and not anemic (Hb ≥12.0 g/dL) at baseline; for FER and sTfR, subgroups were iron deficiency (FER <15 µg/L), marginal iron stores (FER ≥15 and <50 µg/L), and sufficient iron stores (FER ≥50 µg/L) at baseline; for RBP, subgroups were marginal VitA deficiency (RBP <1.05 µmol/L) and no VitA deficiency (RBP ≥1.05 µmol/L) at baseline; and for folate, subgroups were marginal folate deficiency (folate <6 ng/mL) and no folate deficiency (folate ≥6 ng/mL) at baseline.

Changes to procedure

Due to a relatively high number of participants who ceased to work and left the factory (primarily as a result of a change of the main purchaser and a great part of management), the follow-up was preponed by one month in order to minimize the number of further dropouts. Hence, the endline assessment was conducted after five months (beginning of October 2015) instead of after six months. The canteen operated as planned until end of October 2015.

Results

Baseline characteristics

Between 14 March and 4 April 2015, a total of 267 female workers signed the informed consent prior to enrollment (Figure 1). At the enrollment procedure, which took place from 21 to 29 April 2015, 229 workers were present whereas 38 were not (*n*=30 ceased to work and *n*=8 refused to participate). Further six workers were excluded from participation at the clinical screening (*n*=2 with Hb <7.0 g/dL, *n*=2 not nulliparous, *n*=1 with physical handicap, and *n*=1 with chronic disease). The remaining 223 women were randomly assigned and access to free lunch provision for the intervention group started in early May 2015.

The follow-up assessment took place from 1 to 10 October 2015. 172 women (77%) completed the follow-up (*n*=50 ceased to work and *n*=1 became pregnant), with endline data available for anthropometry. Dropouts were equally distributed across groups. The count of incomplete blood values for both time points (due to refused blood sampling, missing aliquot, or deviating duplicate measurement) was low for Hb (*n*=2 of 172), FER, sTfR, RBP, CRP, and AGP (all *n*=4 of 172), but slightly higher for folate (*n*=21 of 172). Follow-up values for VitB12 were not available as described in the methods section. Within the actual intervention period of five months, intervention subjects on average visited the staff canteen on 85% of total days.

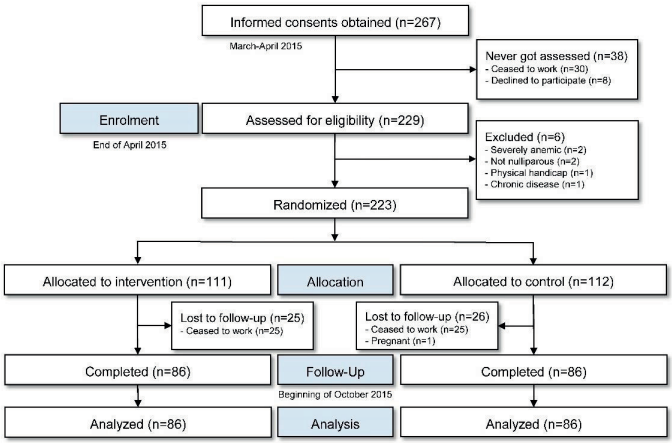

Figure 1. CONSORT flow diagram of the trial.

The intervention group had access to free lunch provision on workdays through a canteen for five months.

Overall, participants had a mean ± SD age of 21 ± 3 years and a total monthly salary of 195 ± 34 USD. Of the total, 94% were single (*n*=162 of 172), 67% stayed at a nearby shared room for rent (*n*=115 of 172), and 63% (*n*=109 of 172) worked as sewer. 63% (*n*=108 of 172) reported a preceding employment in another garment factory. Baseline equivalence amongst groups was given (Table 2), despite a 23% dropout.

Table 2. Baseline characteristics of enrolled female Cambodian garment workers by group.[1]

	Group	
	Intervention	**Control**
Total, n (%)	86 (50)	86 (50)
Age, years	21 ± 3[2]	21 ± 3
Weight, kg	46 ± 6	47 ± 6
Height, cm	153 ± 5	154 ± 6
School attendance, years	7 ± 2	7 ± 2
Marital status, n (%)		
Single	81 (94)	81 (94)
Married	4 (5)	4 (5)
Widowed	1 (1)	1 (1)
Hometown province, n (%)		
Phnom Penh	2 (2)	5 (6)
Others	84 (98)	81 (94)
Duration of employment in factory, months	14 ± 9	13 ± 9
Monthly basic salary, USD	131 ± 14	131 ± 9
Last monthly salary (incl. bonus, overtime, and allowance), USD	198 ± 37	191 ± 31[3]
Job type in factory, n (%)		
Sewing	52 (60)	57 (66)
Quality control	16 (19)	12 (14)
Buttoning	8 (9)	4 (5)
Cutting	4 (5)	3 (3)
Packaging	3 (3)	3 (3)
Others	3 (3)	7 (8)
Accommodation on workdays, n (%)		
Hometown, family household	18 (21)	32 (37)
Nearby place of friend/family	4 (5)	1 (1)
Nearby shared room for rent	63 (73)	52 (60)
Nearby private room for rent	1 (1)	1 (1)
Number of people in family household	4.6 ± 1.4	5.2 ± 1.6
Wealth index of family household	1.9 ± 2.8	2.4 ± 3.6
Participant's monthly payment to family household, USD	119 ± 39	122 ± 41[4]
Family household's primary source of income, n (%)		
Wage employment	46 (53)	54 (63)
Farming	22 (26)	17 (20)
Casual labor	6 (7)	10 (12)
Business/petty trade	7 (8)	4 (5)
Others	5 (6)	1 (1)

[1]Total *n*=172 (completed the follow-up)

[2]Mean ± SD (all such values)

[3]*n*=82 (*n*=4 newcomer (≤1 month of employment) without previous monthly salary from this factory)

[4] *n*=85 (*n*=1 participant without monthly payment to family household)

USD: United States Dollar

Data on the nutritional status and prevalence rates of anemia and micronutrient deficiencies are summarized in Table 3. At baseline, the prevalence of subclinical inflammation was 1% (*n*=1 of 168 (*n*=1 control)) for incubation (CRP >5 mg/L only), 1% (*n*=1 of 168 (*n*=1 control)) for early convalescence (AGP >1 g/L and CRP >5 mg/L), and 7% (*n*=12 of 168 (*n*=4 intervention and *n*=8 control)) for late convalescence (AGP >1

g/L only). At five months, the prevalence was 1% for incubation (*n*=1 of 171 (*n*=1 control)), 1% for early convalescence (*n*=2 of 171 (*n*=2 control)), and 6% (*n*=11 of 171 (*n*=7 intervention and *n*=4 control)) for late convalescence.

Table 3. Nutritional status, anemia, and micronutrient deficiencies at baseline and five months (follow-up) in female Cambodian garment workers by group.[1]

	Group	
	Intervention	**Control**
Underweight[2] (BMI <18.5 kg/m^2)		
Baseline	29/86 (34)	25/86 (29)
At five months	25/86 (29)	23/86 (27)
Normal[3] (BMI ≥18.5 and <25.0 kg/m^2)		
Baseline	54/86 (63)	58/86 (67)
At five months	57/86 (66)	60/86 (70)
Overweight (BMI ≥25.0 and <30.0 kg/m^2)		
Baseline	3/86 (3)	3/86 (3)
At five months	4/86 (5)	3/86 (3)
Anemia[4,5] (Hb <12.0 g/dL)		
Baseline	19/85 (22)	23/85 (27)
At five months	19/85 (22)	22/86 (26)
Iron deficiency[6] (FER[7] <15 µg/L)		
Baseline	15/84 (18)	21/84 (25)
At five months	17/85 (20)	13/86 (15)
Marginal iron stores[6] (FER[7] ≥15 and <50 µg/L)		
Baseline	49/84 (58)	35/84 (42)
At five months	48/85 (56)	46/86 (54)
Tissue iron deficiency[6] (sTfR >8.3 mg/L)		
Baseline	7/84 (8)	10/84 (12)
At five months	5/85 (6)	11/86 (13)
Iron deficiency anemia[6] (Hb <12.0 g/dL and FER[7] <15 µg/L)		
Baseline	8/84 (10)	12/84 (14)
At five months	8/85 (9)	9/86 (10)
Vitamin A deficiency[6] (RBP[7] <0.70 µmol/L)		
Baseline	0/84 (0)	0/84 (0)
At five months	0/85 (0)	0/86 (0)
Marginal vitamin A deficiency[6] (RBP[7] ≥0.70 and <1.05 µmol/L)		
Baseline	7/84 (8)	3/84 (4)
At five months	8/85 (9)	7/86 (8)
Folate deficiency[8] (<3 ng/mL)		
Baseline	0/78 (0)	0/74 (0)
At five months	0/84 (0)	0/84 (0)
Marginal folate deficiency[8] (≥3 and <6 ng/mL)		
Baseline	21/78 (27)	24/74 (32)
At five months	10/84 (12)	18/84 (21)
Vitamin B12 deficiency[9] (<148 pmol/L)		
Baseline	0/83 (0)	1/84 (1)
At five months	NA	NA
Marginal vitamin B12 deficiency[9] (≥148 and <222 pmol/L)		
Baseline	2/83 (2)	5/84 (6)
At five months	NA	NA

[1]Values are *n*/total *n* (%)
[2]Thereof mild underweight (BMI ≥17.0 and <18.5 kg/m^2): at baseline *n*=21/*n*=18 (intervention/control), at five months *n*=19/*n*=14; moderate underweight (BMI ≥16.0 and <17.0 kg/m^2): at baseline *n*=6/*n*=4, at five months *n*=5/*n*=6; severe underweight (BMI <16.0 kg/m^2): at baseline *n*=2/*n*=3, at five months *n*=1/*n*=3
[3]Thereof low-normal BMI (BMI ≥18.5 and <20.0 kg/m^2): at baseline *n*=24/*n*=24, at five months *n*=21/*n*=24
[4]At baseline total *n*=170 (*n*=1/*n*=1 refused blood sampling). At five months total *n*=171 (*n*=1 intervention participant refused blood sampling)
[5]Thereof mild anemia (Hb ≥11.0 and <12.0 g/dL): at baseline *n*=13/*n*=16, at five months *n*=16/*n*=14; moderate anemia (Hb ≥8.0 and <11.0 g/dL): at baseline *n*=6/*n*=7, at five months *n*=3/*n*=8
[6]At baseline total *n*=168 (*n*=1/*n*=1 refused blood sampling, *n*=1/*n*=1 with missing aliquot). At five months total *n*=171 (*n*=1 intervention participant refused blood sampling)
[7]Values adjusted for subclinical inflammation
[8]At baseline total *n*=152 (*n*=1/*n*=1 refused blood sampling, *n*=1/*n*=1 with missing aliquot, *n*=6/*n*=10 with deviating duplicate measurement). At five months total *n*=168 (*n*=1 intervention participant refused blood sampling, *n*=1/*n*=2 with deviating duplicate measurement)
[9]At baseline total *n*=167 (*n*=1/*n*=1 refused blood sampling, *n*=2/*n*=1 with missing aliquot). Values for vitamin B12 not available at five months
BMI: Body mass index; Hb: Hemoglobin; FER: Ferritin; sTfR: Soluble transferrin receptor; RBP: Retinol-binding protein; NA: Not available

Intervention effects on anthropometric variables

The adjusted mean BMI at five months was 0.1 kg/m^2 higher among the intervention group, representing a non-significant, very small to small effect (p=0.27, Cohen's d=0.17). On the other hand, no considerable differences were observed between groups for adjusted mean weight. The adjusted mean TSF among the intervention group was higher by 0.4 mm, also illustrating a non-significant, very small to small effect (p=0.24, Cohen's d=0.18). In contrast, adjusted mean MUAMC at five months was slightly lower, but not significantly, by 0.1 cm (p=0.35, Cohen's d=-0.14) (Table 4). Unadjusted values generally did not deviate from results obtained by adjustment for baseline values (only the unadjusted impact on weight was slightly higher with +0.2 kg).

Table 4. Mean BMI, weight, TSF, and MUAMC at baseline and at five months (follow-up) by group and the intervention effects in female Cambodian garment workers.[1]

	Group		Intervention effect		
	Intervention	**Control**	**Mean difference**	**Cohen's d**	**p**
BMI, kg/m^2					
Baseline	19.8 ± 2.4[2]	19.9 ± 2.4	-	-	-
At five months, unadjusted	19.9 ± 2.3	19.9 ± 2.4	-	-	-
At five months, adjusted	20.0 (19.8, 20.2)[3]	19.9 (19.7, 20.0)	0.1 (-0.1, 0.4)	0.17	0.27
Weight, kg					
Baseline	46.0 ± 6.1	47.4 ± 6.3	-	-	-
At five months, unadjusted	46.4 ± 5.9	47.6 ± 5.9	-	-	-
At five months, adjusted	47.0 (46.7, 47.4)	46.9 (46.5, 47.3)	0.1 (-0.4, 0.7)	0.06	0.64
TSF, mm					
Baseline	15.4 ± 4.5	15.4 ± 4.8	-	-	-
At five months, unadjusted	15.6 ± 4.7	15.2 ± 4.6	-	-	-
At five months, adjusted	15.6 (15.1, 16.0)	15.2 (14.7, 15.7)	0.4 (-0.3, 1.1)	0.18	0.24
MUAMC, cm					
Baseline	19.1 ± 1.4	19.2 ± 1.6	-	-	-
At five months, unadjusted	19.1 ± 1.5	19.3 ± 1.5	-	-	-
At five months, adjusted	19.2 (19.0, 19.3)	19.3 (19.1, 19.4)	-0.1 (-0.3, 0.1)	-0.14	0.35

[1]Total *n*=172 (completed the follow-up, *n*=86 intervention and *n*=86 control). A general linear model with adjustments for baseline values was used to predict marginal means (95% CIs) for each outcome variable and to estimate intervention effects as corresponding marginal mean differences (95% CIs) including an estimated standardized effect size (Cohen's *d*)

[2]Mean ± SD (all such values)

[3]Marginal mean, 95% CI in parentheses (all such values)

BMI: Body mass index; TSF: Triceps skinfold thickness; MUAMC: Mid-upper arm muscle circumference

Subgroup analysis showed that adjusted means of BMI, weight, TSF, and MUAMC among underweight participants (BMI <18.5 kg/m^2) increased in intervention as well as in control subjects, with minor differences observed between groups only for BMI (around +0.4 kg/m² vs. +0.2 kg/m²) and weight (about +1.0 kg vs. +0.6 kg). Differences were also found in participants with low-normal BMI at baseline (BMI ≥18.5 and <20 kg/m^2). Here, the adjusted mean BMI at follow-up was higher by around 0.35 kg/m^2 in the intervention group (around +0.3 kg/m² vs. -0.05 kg/m^2). Mean weight was likewise higher by approximately 0.4 kg (around +0.7 kg vs. +0.3 kg), as well as mean TSF by 0.5 mm (around +0.2 vs. -0.3 mm). On the other hand, the adjusted mean MUAMC was slightly lower by around 0.2 cm in intervention participants. Furthermore, in workers with a BMI ≥20 kg/m^2, mean BMI and mean weight marginally decreased in both groups, with no differences noticed. Adjusted mean TSF at five months was slightly higher by 0.5 mm (around +0.1 mm vs. -0.4 mm), while mean MUAMC was marginally lower by approximately 0.1 cm in the intervention group (Figure 2).

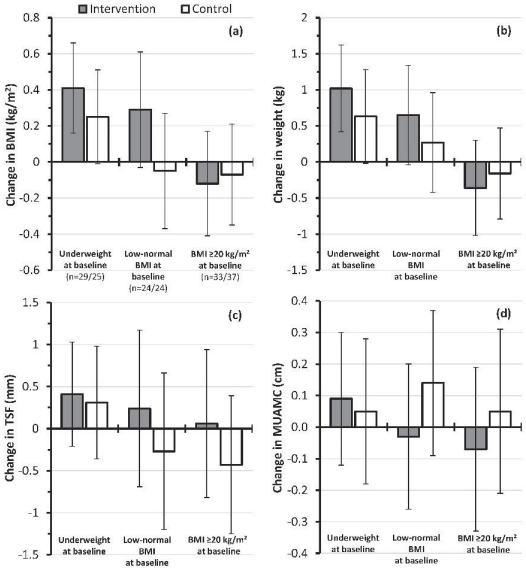

Figure 2. Mean change in (**a**) BMI, (**b**) weight, (**c**) TSF, and (**d**) MUAMC from baseline to five months (follow-up) by group and BMI status at baseline.

Total *n*=172 (completed the follow-up, *n*=86 intervention and *n*=86 control). Thereof underweight (BMI <18.5 kg/m^2) at baseline: *n*=29/*n*=25 (intervention/control); low-normal BMI (BMI ≥18.5 and <20 kg/m^2) at baseline: *n*=24/*n*=24; and BMI ≥20 kg/m^2 at baseline: *n*=33/*n*=37. A general linear model with adjustments for baseline values was used to predict marginal mean changes (95% CIs) for each outcome variable. Whiskers illustrate corresponding 95% CIs. BMI: Body mass index; TSF: Triceps skinfold thickness; MUAMC: Mid-upper arm muscle circumference.

Intervention effects on hemoglobin and micronutrient status

At the end of the intervention (Table 5), the adjusted mean Hb was 0.1 g/dL higher among the intervention group, a non-significant, very small to small positive effect (*p*=0.30, Cohen's *d*=0.17). In contrast, mean FER was lower by 6.6 µg/L, illustrating a significant, small to medium negative effect (*p*=0.015, Cohen's *d*=-0.39). Concurrently, mean sTfR was 0.2 mg/L higher, representing a non-significant, small negative effect (*p*=0.15, Cohen's *d*=0.22). Apart from that, the adjusted mean RBP was 0.05 µmol/L higher among

the intervention group, a non-significant, very small to small positive effect (p=0.27, Cohen's d=0.17). At last, mean folate was higher by 1.1 ng/mL, outlining a marginally significant, small to medium positive effect (p=0.054, Cohen's d = 0.32).

Table 5. Mean Hb, FER, sTfR, RBP and folate concentrations at baseline and at five months (follow-up) by group and the intervention effects in female Cambodian garment workers.[1]

	Group		Intervention effect		
	Intervention	**Control**	**Mean difference**	**Cohen's d**	**p**
Hb, g/dL					
Baseline	12.6 ± 0.9 (85)[2]	12.4 ± 1.0 (85)	-	-	-
At five months, unadjusted	12.6 ± 0.9 (85)	12.3 ± 1.0 (86)	-	-	-
At five months, adjusted[3]	12.5 (12.4, 12.6) (85)[4]	12.4 (12.3, 12.5) (85)	0.1 (-0.1, 0.3)	0.17	0.30
FER, µg/L[5]					
Baseline	40.4 ± 33.8 (84)	44.9 ± 40.0 (84)	-	-	-
At five months, unadjusted	38.0 ± 27.1 (85)	47.4 ± 39.6 (86)	-	-	-
At five months, adjusted[3]	39.3 (35.5, 43.0) (84)	45.8 (42.1, 49.6) (84)	-6.6 (-11.9, -1.3)	-0.39	0.015
sTfR, mg/L					
Baseline	5.8 ± 2.6 (84)	6.3 ± 3.3 (84)	-	-	-
At five months, unadjusted	5.9 ± 2.6 (85)	6.2 ± 3.5 (86)	-	-	-
At five months, adjusted[3]	6.1 (5.9, 6.3) (84)	5.9 (5.7, 6.1) (84)	0.2 (-0.1, 0.5)	0.23	0.15
RBP, µmol/L[5]					
Baseline	1.37 ± 0.26 (84)	1.49 ± 0.31 (84)	-	-	-
At five months, unadjusted	1.42 ± 0.33 (85)	1.44 ± 0.35 (86)	-	-	-
At five months, adjusted[3]	1.45 (1.39, 1.52) (84)	1.40 (1.34, 1.47) (84)	0.05 (-0.04, 0.14)	0.17	0.27
Folate, ng/mL					
Baseline	8.0 ± 3.1 (78)	7.8 ± 2.9 (74)	-	-	-
At five months, unadjusted	9.6 ± 4.5 (84)	8.2 ± 3.2 (84)	-	-	-
At five months, adjusted[3]	9.5 (8.8, 10.3) (78)	8.4 (7.6, 9.2) (73)	1.1 (-0.02, 2.2)	0.32	0.054

[1]A general linear model with adjustments for baseline values was used to predict marginal means (95% CIs) for each outcome variable and to estimate intervention effects as corresponding marginal mean differences (95% CIs) including an estimated standardized effect size (Cohen's *d*)
[2]Mean ± SD, *n* in parentheses (all such values)
[3]Among subjects with data for both time points
[4]Marginal mean, 95% CI and *n* in parentheses (all such values)
[5]Values adjusted for subclinical inflammation
Hb: Hemoglobin; FER: Ferritin; sTfR: Soluble transferrin receptor; RBP: Retinol binding protein

In the secondary subgroup analysis (Figure 3), mean change in Hb differed only among the few women with moderate anemia (Hb ≥8.0 and <11.0 g/dL) at baseline. Here, the adjusted mean Hb at five months was higher by 0.8 g/dL in intervention participants (around +0.6 g/dL vs. -0.2 g/dL). Overall, mean Hb slightly increased among the subjects with mild anemia (Hb ≥11.0 and <12.0 g/dL), and marginally decreased for women not affected by anemia (Hb ≥12.0 g/dL). Mean FER slightly increased, for both groups, among workers affected by iron deficiency (FER <15 µg/L), as well as among the subjects with

marginal iron stores (FER ≥15 and <50 µg/L). However, among women with marginal iron stores, sTfR was higher by 0.4 mg/L in intervention participants (around +0.1 mg/L vs. -0.3 mg/L). On the other hand, mean change in FER clearly differed among groups in subjects with sufficient iron stores (FER ≥50 µg/L) at baseline. Here, mean FER at follow-up was lower by 18 µg/L in the intervention participants. In line with this finding, mean sTfR at five months was higher by 0.3 mg/L in intervention participants (around +0.2 mg/L vs. -0.1 mg/L). The adjusted mean change in RBP differed only among the few women with marginal VitA deficiency (RBP ≥0.70 and <1.05 µmol/L) at baseline. Mean RBP at follow-up was higher by approximately 0.2 µmol/L in intervention participants. Mean folate considerably increased, for both groups, among workers affected by marginal folate deficiency (folate ≥3 and <6 ng/mL), and was higher by 0.7 ng/mL in intervention participants (around +2.2 ng/mL vs. +1.5 ng/mL). Mean change also clearly differed between groups in subjects not affected by folate deficiency (folate ≥6 ng/mL), where folate at five months was higher by 1.2 ng/mL for intervention participants (+1.4 ng/mL compared with +0.2 ng/mL).

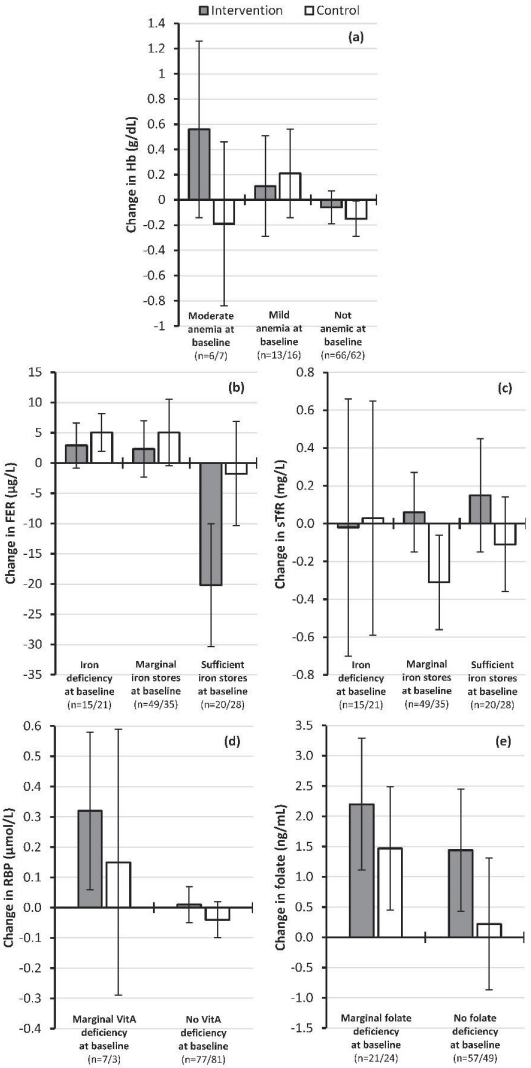

Figure 3. Mean change in (**a**) Hb, (**b**) FER, (**c**) sTfR, (**d**) RBP, and (**e**) folate concentrations from baseline to five months (follow-up) by group and status at baseline.

A general linear model with adjustments for baseline values was used to predict marginal mean changes (95% CIs) for each outcome variable. Whiskers illustrate corresponding 95% CIs. **(a)** Mean change of Hb for subjects with moderate anemia (Hb ≥8.0 and <11.0 g/dL), mild anemia (Hb ≥11.0 and <12.0 g/dL), and no anemia (Hb ≥12.0 g/dL) at baseline. Total *n*=85/*n*=85 (intervention/control). **(b)** Mean change of FER for subjects with iron deficiency (FER <15 µg/L), marginal iron stores (FER ≥15 and <50 µg/L), and sufficient iron stores (FER ≥50 µg/L) at baseline. Total *n*=84/*n*=84. Values adjusted for subclinical inflammation. **(c)** Mean change of sTfR for subjects with iron deficiency, marginal iron stores, and sufficient iron stores at baseline. Total *n*=84/*n*=84. **(d)** Mean change of RBP for subjects with marginal VitA deficiency (RBP <1.05 µmol/L) and no VitA deficiency (RBP ≥1.05 µmol/L) at baseline. Total *n*=84/*n*=84. Values adjusted for subclinical inflammation. **(e)** Mean change of folate for subjects with marginal folate deficiency (folate ≥3 and <6 ng/mL) and no folate deficiency (folate ≥6 ng/mL) at baseline. Total *n*=78/*n*=73. Hb: Hemoglobin; FER: Ferritin; sTfR: Soluble transferrin receptor; RBP: Retinol binding protein; VitA: Vitamin A.

Discussion

Access to a free model lunch provision on workdays for five months for – in their majority not underweight – female Cambodian garment workers resulted in marginally increased mean BMI (+0.1 kg/m²), mean weight (+0.1 kg), mean TSF (+0.4 mm), and a nominal lower mean MUAMC (-0.1 cm). These results, illustrating negligible (Cohen's *d* <0.1) to very small/small (Cohen's *d* ≥0.1 and <0.2) effects, were all statistically not significant and are assumed to represent, if any, a very limited general intervention impact on worker's anthropometry. But, a subgroup analysis reveals a more pronounced positive intervention impact on weight (around +0.4 kg) and BMI (up to +0.35 kg/m²) among underweight participants (BMI <18.5 kg/m^2) and those with a low-normal BMI (BMI ≥18.5 and <20 kg/m^2). Furthermore, in subjects with low-normal BMI and those with a BMI ≥20 kg/m^2, TSF was thicker by 0.5 mm. Although not being suited to test for statistical significance (given the small sample sizes within subgroups), such effects actually correspond to small to medium effect sizes (Cohen's *d* between ≥0.2 and <0.5). Noteworthy, the means in BMI, weight, and TSF, increased in underweight control participants and decreased in control subjects with a BMI ≥20 kg/m^2, which might be due to regression to the mean.

Similar studies with garment workers are almost non-existent. Food provision trials in low-income countries primarily focus on school feeding programs. Interestingly, evidence of the impact on

anthropometric indices remains inconclusive [38]. In Cambodia, the recent ILO multi-factory study reported that one year of daily food provision did not induce changes of the mean BMI of Cambodian garment workers (detailed data are not provided though) [9]. However, food provision within the ILO study differed substantially in its intervention factories (ranging from various morning or afternoon snacks to full lunches). Therefore, comparisons are difficult to draw. Moreover, ILO-study participants were distinctly older and to a lesser extent affected by underweight than workers in the study reported here.

Effects from lunch provision on worker's anthropometric indices might have been weakened due to the frequent onset of infectious diseases, as infections are known to have a negative impact on the nutritional status [39]. At baseline, study participants often reported symptoms of respiratory tract infections, fever, and diarrhea, and tended to continue work despite being sick [6].

The study concomitantly collected qualitative data on the individual dietary intake through 24h-recalls among all participants at several interviews during the intervention [40]. Corresponding results indicate that some participants (regardless of whether in intervention or control arm) tended to skip breakfasts, but hardly ever skipped lunch meals. Therefore, providing lunch to garment workers eventually replaces meals that are otherwise eaten by the women, mostly low-price options from nearby street vendors and/or home prepared food items. Consequently, total dietary surplus (e.g. of calories, one prerequisite to expect effects on anthropometry) through lunch provision might be indeed restricted. Although skipping of breakfasts somewhat increased in intervention subjects, no significant differences in skipping breakfasts between groups were observed [40]. Yet, skipping of meals in workers with access to a staff canteen should be closely monitored in order to avoid unfavorable dietary changes. Moreover, a distinct lower consumption of energy-dense sweets/sugared beverages was noted in intervention participants (widely consumed by workers at lunch breaks). This effect is regarded as beneficial for the prevention of non-communicable chronic diseases although it also lowers total energy intake [41].

On average, the model lunch sets provided around one-third of RDA or adequate intake of energy (697 of 2115 kcal/day), carbohydrates, fat, and dietary fiber, while the contribution to RDA of protein was somewhat higher with 46% [17]. Overall, lunches matched recommendations on the energy content of lunch provision through canteens [42], as well as recommendations for sources of food energy [43]. Nevertheless, the RDA of 2115 kcal/day [18] might underestimate energy requirements among garment workers, notably in those with a BMI <20 kg/m² and those exposed to heavy work load and/or overtime work. Consequently, an adjusted higher amount of calories during lunch provision might be needed to achieve a stronger effect on the BMI of laborers with suboptimal nutritional status. On the other hand, any lunch provision program of this kind should also consider the presence of normal weight and overweight workers.

The evaluation of the impact on Hb and micronutrient status showed an overall small-sized non-significant positive trend for mean Hb (+0.1 g/dL) and mean RBP (+0.05 µmol/L), as well as a marginally significant small-sized positive effect on folate (+1.1 ng/mL). At the same time, intervention subjects showed a significantly lower mean FER (-6.6 µg/L) at five months, equivalent to a small to medium negative intervention effect (Cohen's *d* of -0.4). In line with this finding, mean sTfR concentration among intervention participants was higher by 0.2 mg/L, however, this small-sized effect (Cohen's *d* of 0.2) was not significant.

The subgroup analysis suggests that positive effects on Hb and RBP concentrations are more pronounced (+0.8 g/dL and +0.17 µmol/L, respectively) in workers with initial moderate anemia (Hb ≥8.0 and <11.0 g/dL) and those affected by marginal VitA deficiency (RBP ≥0.70 and <1.05 µmol/L), corresponding to a medium to large positive effect size (Cohen's *d* between 0.5 and 1.0). However, only very few participants showed these conditions at baseline. Therefore, no definite inferences can be stated. The positive impact on mean folate (corresponding to a small positive effect size with Cohen's *d* of ~0.3) was noted in intervention subjects with marginal folate deficiency (folate ≥3 and <6 ng/mL), as well as in those with adequate folate status (≥6 ng/mL) at baseline. The lowering effect on iron stores occurred notably in workers with sufficient iron stores at baseline (FER ≥50 µg/L). In addition, sTfR values increased in

intervention participants with marginal iron stores (FER ≥15 and <50 µg/L) and those with sufficient iron stores, but they decreased in same subgroups of control participants.

The lunch sets provided had a low mean iron content (6 mg, equaling 20% of RDA) [17]. Due to their relatively high price, animal source foods (chicken and pork meat, as well as various fish) were served in small portion sizes of ~50 g/day, equaling 0.5 - 1.7 mg iron per 100 g edible portion [17,44–46]. Consequently, most of the dietary iron was provided as less bioavailable nonheme iron in vegetables, fruits, and rice [17]. As vitamin C enhances nonheme iron absorption, sets provided on average a relatively high amount of vitamin C (159% of RDA). But, the effect might have been limited in a complete menu containing various components known to inhibit iron intake [47,48]. Although data on the dietary iron intake among Cambodian garment workers are missing, the lunch sets provided could have contained less iron than lunches eaten by the workers outside the factory gates. The incorporation of alternative and affordable heme iron-rich food items (e.g. blood curd, liver, or small fish like Mekong flying barb) could constitute a better option to increase the iron content than just increasing the serving sizes of rather costly meat/fish components in lunch sets [17,49–51].

If the obtained overall finding in terms of Hb represents an intervention effect can be questioned. Moreover, the unadjusted mean Hb actually remained unchanged in intervention participants. This is not indicating a failure as about three out of four study subjects were not anemic (Hb ≥12.0 g/dL) at baseline. Therefore, distinct positive effects on mean Hb concentration could not be expected from the intervention among non-anemic participants. On the other hand, the observed changes in mean Hb among subjects affected by moderate anemia are considered relevant.

The prevalence of anemia in the study population was initially expected to be higher, since national data indicate that 45% of Cambodian women of reproductive age are anemic [22]. The recent ILO survey reported a similar high prevalence in female garment workers [9]. In general, iron deficiency is believed to be the primary cause of anemia [10]. However, as previously mentioned, the iron content of the studied

lunch sets was relatively low [17]. On the other hand, iron deficiency can only partially explain anemia in this study population [6], as the prevalence of iron deficiency anemia (simultaneous anemia and iron deficiency) among subjects was solely 12%. The contributors to the prevalence of anemia in Cambodia are still debated and measures to improve zinc and folate status, as well as to treat and prevent hookworm infections, have been suggested [52]. Genetic disorders, e.g. Hb E variants and α-thalassemia, are reported to affect >50% of the Cambodian population, causing lower Hb concentrations and an increased risk for anemia regardless of iron stores [15,52–55]. Although not assessed in this trial, it is likely that hemoglobinopathies contribute to the prevalence of anemia among study participants. In a recent one-year randomized controlled trial, neither iron ingots added to cooking pots nor daily iron supplements (18 mg/d) increased Hb concentration in anemic Cambodian women [56]. In comparison, daily high-dose iron supplementation (60 mg/d) for 12 weeks increased Hb in a female study population in Cambodia, while added multiple micronutrients did not confer additional benefits [54].

The lunch sets served were estimated to provide 66% of the RDA for RAE on average, given the regular serving of provitamin A-rich vegetables and fruits [17]. However, none of the study subjects were affected by frank VitA deficiency (RBP <0.70 µmol/L) and only few participants showed a marginal VitA status at baseline, which is in line with recent national representative data for women of reproductive age [33,52]. The uptake of VitA from the diet is under homeostatic control [57], consequently, no effects on mean RBP concentrations could be expected in VitA-replete subjects. The overall small-sized non-significant effect on increasing RBP, is largely based on the increase of mean RBP in few intervention subjects with marginal VitA deficiency, which is expected to be relevant, but confirmation is needed in a larger study including more participants with suboptimal VitA status. At the time of planning, the study population was expected to be more affected by a poor VitA status, given foregoing findings [58].

The intervention had a marginally significant small-sized positive impact on mean folate concentration, suggesting that lunch sets provided a relevant amount of dietary folate. The estimated mean folate content among sets was 175 µg (corresponding to 44% of the SEA-RDA [18]), whereby dark green leafy vegetables

and fruits were the main sources [17]. In addition, missing folate data in local food composition tables certainly led to an underestimation for some lunch sets [17]. The finding on the prevalence of marginal folate deficiency among workers is in line with previous reports that suggest measures to increase folate/folic acid intake of Cambodian women [52]. Noteworthy, according to the subgroup analysis, the effect on folate status not only concerned participants with marginal folate deficiency, but also subjects with adequate folate status. However, a part of the increase in folate concentration among intervention participants with marginal folate status can be attributed to the upregulation of folate uptake from the diet [59], as represented by the increase in mean folate in control participants with a marginal folate status.

Limitations of the study

Results of this study are closely related to the setting and the specific study population. However, the status of the laborers and the working conditions were assumed to be comparable with general conditions in the Cambodian garment industry. Moreover, the study's inclusion criteria represented a greater part of workers employed by this sector.

The model lunch could not be based on the study's baseline findings [6] nor on any other previous gap-oriented assessment among Cambodian garment workers. An appropriate intervention duration, as well as proper amounts of calories or micronutrients, to specifically target underweight, anemia and/or micronutrient deficiencies, could not be established beforehand. Furthermore, the estimation of the lunches' effective nutritive value was limited [17]. For instance, no information was available about components known to inhibit iron bioavailability from the food provided.

The study aimed to enroll 330 participants and to collect follow-up data among 260 of them (130 subjects in each arm). However, fear and skepticism related to the blood sampling procedure were reported by many workers, especially due to headlines about a severe HIV outbreak caused by unlicensed clinicians reusing syringes shortly before enrollment [60]. Moreover, the factory unexpectedly changed its main purchaser and a part of its management team at the time when the study started. As a consequence, a part of the total

factory staff, and therefore also a relatively high number of workers who had already signed consents or were already enrolled, ceased the work and left the factory between April and June 2015. Almost all study dropouts fell in this period. Yet, they were equally distributed across groups and their sociodemographic characteristics were comparable to those who completed the study (data not shown). Given the high fluctuation rate, the impact assessment was performed after five months already. As the number of full data sets for the calculation of intervention effects was smaller than targeted, this limited the statistical power and the effect sizes that could be measured. In line with guidelines for exploratory studies, no corrections for multiple comparisons have been made [61].

Only a part of the enrolled workers where actually affected by underweight, anemia and/or micronutrient deficiencies. However, direct improvements can only be expected in malnourished individuals. The calculation of the sample size of future studies may consider the initial prevalence of malnutrition.

The prevalence of hemoglobinopathies, which are likely to be a contributing factor to anemia, was not measured. Inherited hemoglobin disorders are also known to impact on markers of iron status [15,62]. In this regard, sTfR concentration as sole indicator of iron status appears to be less reliable in the Cambodian context [62]. Furthermore, menstrual blood loss, a determinant of iron stores in women of reproductive age [63], could not be recorded.

Conclusions

The objective of this study was to determine the effects of an exemplary workdays low-price lunch provision through a canteen on anthropometry, Hb, and micronutrient status in female workers employed by a garment factory in Phnom Penh, Cambodia. After five months, anthropometric variables merely showed non-significant marginal distinctions between the intervention and the control group (equaling negligible or very small to small effect sizes). Yet, subgroup analysis prompts that effects differ according to the nutritional status of workers. For instance, the positive impact on BMI was found more pronounced in women with a poor or marginal nutritional status.

Overall, only minor non-significant positive differences were noticed in Hb and VitA status for the intervention participants (very small to small effects). Specific results indicate that the model lunch sets need to be revisited for iron content and/or iron bioavailability, as interventions subjects, in particular participants with sufficient iron stores, showed significantly lower FER values at the follow-up (small to medium effect). On the other hand, endline folate status was higher in workers with access to the lunch provision (marginally significant small to medium positive effect), suggesting that lunch sets provided a beneficial amount of dietary folate.

In conclusion, workdays lunch provision through a canteen for Cambodian garment workers is feasible and has the potential to result in distinct positive effects on anthropometry, Hb, and micronutrient status, particularly in malnourished individuals. The authors suggest that similar trials with larger study populations, which include lunch sets adapted to identified requirements of workers affected by underweight, anemia and/or definite micronutrient deficiencies, should be performed. The overall findings from this study should have practical implications for the design and implementation of subsequent studies, lunch programs, and further strategies aiming at the improvement of the nutritional situation of female garment workers in Cambodia.

List of abbreviations

USD: United States Dollar
NGO: Non-government organization
ILO: International Labour Organization
VitA: Vitamin A
VitB12: Vitamin B12
LUPROGAR: Lunch Provision in Garment Factories
Hb: Hemoglobin
RDA: Recommended dietary allowance
Kcal: Kilocalories
Min.: Minimum
Max.: Maximum
AI: Adequate intake
RAE: Retinol activity equivalent
TSF: Triceps skinfold thickness
MUAC: Mid upper-arm circumference
CDC: Centers for Disease Control and Prevention

UNICEF: United Nations Children's Emergency Fund
WFP: World Food Programme
BMI: Body mass index
MUAMC: Mid upper-arm muscle circumference
RPM: Revolutions per minute
FER: Ferritin
sTfR: Soluble transferrin receptor
RBP: Retinol binding protein
CRP: C-reactive protein
AGP: α1-acid-glycoprotein
CI: Confidence interval
SD: Standard deviation
SEA: Southeast Asia
HIV: Human immunodeficiency virus

Declarations

Ethics approval and consent to participate

This trial was conducted according to the guidelines laid down in the Declaration of Helsinki. Ethical approval on all procedures was obtained from the Institutional Review Board of the Faculty of Medicine at Justus Liebig University, Giessen, Germany (14 November 2014, Identifier: 198/14) and the National Ethics Committee for Health Research at the Ministry of Health, Phnom Penh, Cambodia (29 December 2014, Identifier: 0363 NECHR). Written informed consent was collected from all subjects. Participants were informed that they could leave the study at any time.

Consent for publication

Not applicable.

Availability of data and material

The datasets generated and analyzed during the study are not publicly available due the terms of consent to which the participants agreed but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

J.M. and M.B.K. conceived and designed the LUPROGAR trial; J.M. and N.B. conducted the field work and managed the data; F.T.W. and C.C. supported and supervised data collection in the field; J.M. conducted the statistical analysis of the data; J.M. wrote the initial manuscript; all authors contributed to the review and editing of the manuscript to the final version; and J.M. and M.B.K. had primary responsibility for the final content. All authors read and approved the final version of the manuscript.

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References

1. International Labour Organization. *Cambodian Garment and Footwear Sector Bulletin. Issue 6. What explains strong export and weak employment figures in the Cambodian garment sector?*; International Labour Organization: Phnom Penh, Cambodia, **2017**.
2. Bargawi, O. *Cambodia's Garment Industry - Origins and Future Prospects*; Overseas Development Institute: London, UK, **2005**.
3. Asuyama, Y.; Neou, S. How has the Cambodian garment industry evolved? In *Dynamics of the Garment Industry in Low-Income Countries: Experience of Asia and Africa*; Fukunishi, T., Ed.; Japan External Trade Organization: Chiba, Japan, **2012**.
4. International Labour Organization. *Cambodian Garment and Footwear Sector Bulletin. Issue 5. Recent trade policy developments and possible implications for Cambodia's garment and footwear sector*; International Labour Organization: Phnom Penh, Cambodia, **2017**.
5. McMullen, A. *Shop`til They Drop. Fainting and Malnutrition in Garment Workers in Cambodia*; Labour Behind the Label & Community Legal Education Centre: Phnom Penh, Cambodia, **2013**.
6. Makurat, J.; Friedrich, H.; Kuong, K.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Nutritional and micronutrient status of female workers in a garment factory in Cambodia. *Nutrients* **2016**, 8, 694.
7. Kang, C.; Liv, D. *Living Wage Survey for Cambodia's Garment Industry*; Cambodia Institute of Development Study: Phnom Penh, Cambodia, **2009**.
8. International Labour Organization; World Bank. *Cambodia. Women and Work in the Garment Industry*; International Labour Organization: Phnom Penh, Cambodia, **2006**.
9. International Labour Organization. *Garment Workers' Health and Nutrition Status, and Food Provision in Factories. A Study from Selected Enterprises in Cambodia*; International Labour Organization: Phnom Penh, Cambodia, **2016**.
10. World Health Organization. *Iron Deficiency Anaemia. Assessment, Prevention, and Control*: *A Guide for Programme Managers*; World Health Organization: Geneva, Switzerland, **2001**.
11. World Health Organization. *Physical Status: The Use and Interpretation of Anthropometry*: *Report of a WHO Expert Committee*; World Health Organization: Geneva, Switzerland, **1995**.
12. Black, R.E.; Victora, C.G.; Walker, S.P.; Bhutta, Z.A.; Christian, P.; Onis, M. de; Ezzati, M.; Grantham-McGregor, S.; Katz, J.; Martorell, R.*; et al.* Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* **2013**, 382, 427–451.
13. Koury, M.J.; Ponka, P. New insights into erythropoiesis: the roles of folate, vitamin B12, and iron. *Annual Review of Nutrition* **2004**, 24, 105–131.
14. Charles, C.V.; Summerlee, A.J.; Dewey, C.E. Anemia in Cambodia: prevalence, etiology and research needs. *Asia Pacific Journal of Clinical Nutrition* **2012**, 21, 171–181.
15. Karakochuk, C.D.; Whitfield, K.C.; Barr, S.I.; Lamers, Y.; Devlin, A.M.; Vercauteren, S.M.; Kroeun, H.; Talukder, A.; McLean, J.; Green, T.J. Genetic hemoglobin disorders rather than iron deficiency are a major predictor of hemoglobin concentration in women of reproductive age in rural Prey Veng, Cambodia. *The Journal of Nutrition* **2015**, 145, 134–142.
16. BDLINK; HRINC. *Study on the Perceptions of Garment Factory Owners on Nutrition and the Feasibility for Pursuing Canteen Services in the Garment Sector in Cambodia*; International Labour Organization: Phnom Penh, Cambodia, **2012**.
17. Makurat, J.; Pillai, A.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Estimated nutritive value of low-price model lunch sets provided to garment workers in Cambodia. *Nutrients* **2017**, 9, 782.

18. Barba, C.V.; Cabrera, M.I. Recommended dietary allowances harmonization in Southeast Asia. *Asia Pacific Journal of Clinical Nutrition* **2008**, 17 (Suppl 2), 405–408.
19. Nishida, C.; Martinez Nocito, F. FAO/WHO scientific update on carbohydrates in human nutrition: introduction. *European Journal of Clinical Nutrition* **2007**, 61 (Suppl 1), S1-4.
20. Khan, N.C.; van Hoan, P. Vietnam recommended dietary allowances 2007. *Asia Pacific Journal of Clinical Nutrition* **2008**, 17 (Suppl 2), 409–415.
21. Food and Nutrition Board, Institute of Medicine of the National Academies. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty acids, Cholesterol, Protein and Amino Acids*; The National Academies Press: Washington DC, USA, **2005**.
22. National Institute of Statistics; Directorate General for Health; ICF International. *Cambodia Demographic and Health Survey 2014*; National Institute of Statistics; Directorate General for Health; ICF International: Phnom Penh, Cambodia and Rockville, Maryland, USA, **2015**.
23. Centers for Disease Control and Prevention. *National Health and Nutrition Examination Survey (NHANES). Anthropometry Procedures Manual*; Centers for Disease Control and Prevention: Atlanta GA, USA, **2007**.
24. Morisaki, N.; Nagata, C.; Jwa, S.C.; Sago, H.; Saito, S.; Oken, E.; Fujiwara, T. Pre-pregnancy BMI-specific optimal gestational weight gain for women in Japan. *Journal of Epidemiology* **2017**, 27, 492–498.
25. Gibson, R. S. *Principles of Nutritional Assessment*; Oxford University Press: New York, New York, USA, **2005**.
26. Erhardt, J.G.; Estes, J.E.; Pfeiffer, C.M.; Biesalski, H.K.; Craft, N.E. Combined measurement of ferritin, soluble transferrin receptor, retinol binding protein, and C-reactive protein by an inexpensive, sensitive, and simple sandwich enzyme-linked immunosorbent assay technique. *The Journal of Nutrition* **2004**, 134, 3127–3132.
27. Pfeiffer, C.M.; Zhang, M.; Lacher, D.A.; Molloy, A.M.; Tamura, T.; Yetley, E.A.; Picciano, M.-F.; Johnson, C.L. Comparison of serum and red blood cell folate microbiologic assays for national population surveys. *The Journal of Nutrition* **2011**, 141, 1402–1409.
28. Thurnham, D.I.; McCabe, L.D.; Haldar, S.; Wieringa, F.T.; Northrop-Clewes, C.A.; McCabe, G.P. Adjusting plasma ferritin concentrations to remove the effects of subclinical inflammation in the assessment of iron deficiency: a meta-analysis. *The American Journal of Clinical Nutrition* **2010**, 92, 546–555.
29. Milman, N. Iron in pregnancy: how do we secure an appropriate iron status in the mother and child? *Annals of Nutrition & Metabolism* **2011**, 59, 50–54.
30. Thurnham, D.I.; Northrop-Clewes, C.A.; Knowles, J. The use of adjustment factors to address the impact of inflammation on vitamin A and iron status in humans. *The Journal of Nutrition* **2015**, 145, 1137S-1143S.
31. Gamble, M.V.; Ramakrishnan, R.; Palafox, N.A.; Briand, K.; Berglund, L.; Blaner, W.S. Retinol binding protein as a surrogate measure for serum retinol: studies in vitamin A-deficient children from the Republic of the Marshall Islands. *The American Journal of Clinical Nutrition* **2001**, 73, 594–601.
32. Thurnham, D.I.; McCabe, G.P.; Northrop-Clewes, C.A.; Nestel, P. Effects of subclinical infection on plasma retinol concentrations and assessment of prevalence of vitamin A deficiency: meta-analysis. *Lancet* **2003**, 362, 2052–2058.

33. Wieringa, F.T.; Sophonneary, P.; Whitney, S.; Mao, B.; Berger, J.; Conkle, J.; Dijkhuizen, M.A.; Laillou, A. Low prevalence of iron and vitamin A deficiency among Cambodian women of reproductive age. *Nutrients* **2016**, 8, 197.
34. World Health Organization. *Serum and Red Blood Cell Folate Concentrations for Assessing Folate Status in Populations*; World Health Organization: Geneva, Switzerland, **2012**.
35. Allen, L.H. How common is vitamin B-12 deficiency? *The American Journal of Clinical Nutrition* **2009**, 89, 693S-696S.
36. Cohen, J. A power primer. *Psychological Bulletin* **1992**, 112, 155–159.
37. Filmer, D.; Pritchett, L.H. Estimating wealth effects without expenditure data--or tears: an application to educational enrollments in states of India. *Demography* **2001**, 38, 115–132.
38. Jomaa, L.H.; McDonnell, E.; Probart, C. School feeding programs in developing countries: impacts on children's health and educational outcomes. *Nutrition Reviews* **2011**, 69, 83–98.
39. Krawinkel, M.B. Interaction of nutrition and infections globally: an overview. *Annals of Nutrition & Metabolism* **2012**, 61 (Suppl 1), 39–45.
40. Makurat, J.; Kretz, E.C.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Dietary diversity in Cambodian garment workers: the role of free lunch provision. *Nutrients* **2018**, 10, 1010.
41. World Health Organization. *Guideline: Sugars Intake for Adults and Children*; World Health Organization: Geneva, Switzerland, **2015**.
42. German Nutrition Society (DGE). *DGE-Qualitätsstandard für die Betriebsverpflegung*; German Nutrition Society (DGE): Bonn, Germany, **2015**.
43. FAO/WHO/UNU. *Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation, Rome, 17-24 October 2001*; FAO: Rome, Italy, **2004**.
44. SMILING Consortium Group. *Food Composition Table for Cambodia*; Food and Agricultural Organization: Rome, Italy, **2013**.
45. Institute of Nutrition, Mahidol University, Thailand. *ASEAN Food Composition Database*; Institute of Nutrition, Mahidol University: Bangkok, Thailand, **2014**.
46. National Institute of Nutrition Vietnam. *Nutritive Composition Table of Vietnamese Foods*; National Institute of Nutrition Vietnam: Hanoi, Vietnam, **2000**.
47. Collings, R.; Harvey, L.J.; Hooper, L.; Hurst, R.; Brown, T.J.; Ansett, J.; King, M.; Fairweather-Tait, S.J. The absorption of iron from whole diets: a systematic review. *The American Journal of Clinical Nutrition* **2013**, 98, 65–81.
48. Cook, J.D.; Reddy, M.B. Effect of ascorbic acid intake on nonheme-iron absorption from a complete diet. *The American Journal of Clinical Nutrition* **2001**, 73, 93–98.
49. Roos, N.; Thorseng, H.; Chamnan, C.; Larsen, T.; Gondolf, U.H.; Bukhave, K.; Thilsted, S.H. Iron content in common Cambodian fish species: perspectives for dietary iron intake in poor, rural households. *Food Chemistry* **2007**, 104, 1226–1235.
50. Roos, N.; Wahab, M.A.; Chamnan, C.; Thilsted, S.H. The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. *The Journal of Nutrition* **2007**, 137, 1106–1109.
51. Kongkachuichai, R.; Napatthalung, P.; Charoensiri, R. Heme and nonheme iron content of animal products commonly consumed in Thailand. *Journal of Food Composition and Analysis* **2002**, 15, 389–398.
52. Wieringa, F.; Dahl, M.; Chamnan, C.; Poirot, E.; Kuong, K.; Sophonneary, P.; Sinuon, M.; Greuffeille, V.; Hong, R.; Berger, J.*; et al.* The high prevalence of anemia in Cambodian children and

women cannot be satisfactorily explained by nutritional deficiencies or hemoglobin disorders. *Nutrients* **2016**, 8, 348.
53. Carnley, B.P.; Prior, J.F.; Gilbert, A.; Lim, E.; Devenish, R.; Sing, H.; Sarin, E.; Guhadasan, R.; Sullivan, S.G.; Wise, C.A.*; et al.* The prevalence and molecular basis of hemoglobinopathies in Cambodia. *Hemoglobin* **2006**, 30, 463–470.
54. Karakochuk, C.D.; Barker, M.K.; Whitfield, K.C.; Barr, S.I.; Vercauteren, S.M.; Devlin, A.M.; Hutcheon, J.A.; Houghton, L.A.; Prak, S.; Hou, K.*; et al.* The effect of oral iron with or without multiple micronutrients on hemoglobin concentration and hemoglobin response among nonpregnant Cambodian women of reproductive age: a 2 x 2 factorial, double-blind, randomized controlled supplementation trial. *The American Journal of Clinical Nutrition* **2017**, 106, 233–244.
55. Weatherall, D.J.; Clegg, J.B. Inherited haemoglobin disorders: an increasing global health problem. *Bulletin of the World Health Organization* **2001**, 79, 704–712.
56. Rappaport, A.I.; Whitfield, K.C.; Chapman, G.E.; Yada, R.Y.; Kheang, K.M.; Louise, J.; Summerlee, A.J.; Armstrong, G.R.; Green, T.J. Randomized controlled trial assessing the efficacy of a reusable fish-shaped iron ingot to increase hemoglobin concentration in anemic, rural Cambodian women. *The American Journal of Clinical Nutrition* **2017**, 106, 667–674.
57. Tanumihardjo, S.A.; Russell, R.M.; Stephensen, C.B.; Gannon, B.M.; Craft, N.E.; Haskell, M.J.; Lietz, G.; Schulze, K.; Raiten, D.J. Biomarkers of nutrition for development (BOND)-vitamin A review. *The Journal of Nutrition* **2016**, 146, 1816S-48S.
58. Anderson, V.P.; Jack, S.; Monchy, D.; Hem, N.; Hok, P.; Bailey, K.B.; Gibson, R.S. Co-existing micronutrient deficiencies among stunted Cambodian infants and toddlers. *Asia Pacific Journal of Clinical Nutrition* **2008**, 17, 72–79.
59. Said, H.M.; Chatterjee, N.; Haq, R.U.; Subramanian, V.S.; Ortiz, A.; Matherly, L.H.; Sirotnak, F.M.; Halsted, C.; Rubin, S.A. Adaptive regulation of intestinal folate uptake: effect of dietary folate deficiency. *American Journal of Physiology - Cell Physiology* **2000**, 279, C1889-95.
60. Seangly, P. & Cuddy, A. Doctor gets 25 years for HIV outbreak. *The Phnom Penh Post*, 4 December **2015**.
61. Bender, R.; Lange, S. Adjusting for multiple testing--when and how? *Journal of Clinical Epidemiology* **2001**, 54, 343–349.
62. Karakochuk, C.D.; Whitfield, K.C.; Rappaport, A.I.; Barr, S.I.; Vercauteren, S.M.; McLean, J.; Prak, S.; Hou, K.; Talukder, A.; Devenish, R.*; et al.* The homozygous hemoglobin EE genotype and chronic inflammation are associated with high serum ferritin and soluble transferrin receptor concentrations among women in rural Cambodia. *The Journal of Nutrition* **2015**, 145, 2765–2773.
63. Harvey, L.J.; Armah, C.N.; Dainty, J.R.; Foxall, R.J.; John Lewis, D.; Langford, N.J.; Fairweather-Tait, S.J. Impact of menstrual blood loss and diet on iron deficiency among women in the UK. *The British Journal of Nutrition* **2005**, 94, 557–564.

6. Discussion[f]

Synopsis of main findings

The evaluation of the trial's baseline data (chapter 2) showed a relatively high prevalence of underweight, anemia, poor iron status (iron deficiency or marginal iron stores), and self-reported sicknesses among study subjects. On the other hand, participants were not affected by frank VitA or VitB12 deficiency. The BMI of garment workers was associated with serum FER (negative) and serum RBP concentrations (positive), but the association was not strong in both variables. Low Hb and iron deficiency affected both, underweight and not underweight workers, unexpectedly with a higher prevalence of iron deficiency and iron deficiency anemia among not underweight participants.

The estimation of the nutritive value of LUPROGAR's low-price model lunch sets (chapter 3) illustrated that meals satisfied recommendations of caloric content and macronutrient composition for sources of energy intake. Sets provided roughly one-third of the RDA or adequate intake of energy, carbohydrates, fat, and dietary fiber. The contribution towards the RDA of protein was somewhat higher. Furthermore, the exemplary lunch sets contained a high mean share of VitC, VitA, and folate, but were rather low in VitB12 and iron.

The comparison of food consumption by subjects with (intervention) and without access (control) to the model lunch provision (chapter 4) demonstrated that the intervention resulted in a more frequent consumption of dark green leafy vegetables (DGLV), VitA-rich fruits, other fruits, and oils and fats during lunch breaks. In contrast, flesh meats, legumes, nuts and seeds, as well as sweets, were eaten at a lower frequency. Except for a higher consumption rate of VitA-rich fruits and a lower intake frequency of sweets, the model lunch provision had a less clear impact on total 24-h intake from different food groups and was not associated with a higher WDDS.

The conclusive analysis of the impact of LUPROGAR's lunch provision on anthropometry, Hb, and micronutrient status revealed that mean changes in anthropometric variables (BMI, weight, TSF, and MUAMC), Hb, and serum RBP concentration were small-sized and not significant

[f] Parts of this chapter rest upon sections from papers related to this thesis [1–4].

among intervention subjects. Mean serum folate concentration slightly increased, representing a marginally significant positive intervention effect. In contrast, mean serum FER concentration significantly decreased. A subgroup analysis prompts that, for some outcomes, effects are differently pronounced according to the baseline status of workers. For instance, the positive impact on BMI might be more distinct in workers with a poor or marginal nutritional status.

Research outcomes in a wider frame

The findings from chapter 2 highlight that measures need to be developed and implemented for improving the nutritional, Hb, micronutrient, and health status of young Cambodian garment workers. The relatively high prevalence of underweight, anemia, poor iron status, and self-reported sicknesses in LUPROGAR's study participants at baseline gives reason for concern. According to the World Health Organization (WHO), the prevalence of underweight and anemia in study subjects can be considered a critical situation and a public health problem [5,6]. Furthermore, about two-thirds of study subjects (iron deficient or with marginal iron stores) will have a high risk for iron deficiency when they get pregnant [7]. Of interest, low Hb and iron deficiency affected those underweight as well as those normal and overweight (unexpectedly with a higher prevalence among women with a BMI $\geq$18.5 kg/m^2), a fact that should be taken into consideration when conceiving interventions. It is assumed that any betterment of the workers' nutritional and health status will also inherit benefits for garment factory owners, for example resulting in increased productivity.

Given the above mentioned results, many young women will presumably start their employment having a poor nutritional status, as shown for adolescent garment workers in Bangladesh [8]. Underweight is especially widespread among young Cambodian women aged 15-19 years [9]. In accordance with previous socio-economic surveys [10–12], the disposable income of study participants was mainly determined by remittances. Despite the recent rise in minimum salaries, as seen for the Cambodian garment sector within the last years [13], it is assumed that higher salaries might not automatically lead to improved nutrition among workers, as they will continue to fulfil an important contribution to the social securing of their families. In 2017, a national health insurance system for employees was installed in the Cambodian garment sector [13]. It is presumed

that this will bring positive effects on lowering the high prevalence of sicknesses as well as on workers' tendency to work despite being sick.

Chapter 3 provides information on the setup and operation of staff canteens in Cambodian garment factories, since data on exemplary meals/menus, their nutritive value and contribution towards RDAs, as well as their associated costs, are scarce. Findings could contribute to the establishment of guidelines on meal provision in factories and can be used to review any planned or ongoing lunch provision programs. Considering the nutritional and socio-economic situation of Cambodian garment workers, it is believed that a low-price meal provision, similar to the one presented here, has the potential to significantly improve food security of workers, even at costs of less than 1 USD/person/day (at large scale). However, adjustments to the proposed model lunch sets are suggested in order to achieve a higher iron content as the average total iron content among LUPROGAR's meals was relatively low (6 mg, equaling 20% RDA). One strategy to increase the iron content of lunch sets could be to include blood curd and liver (common heme iron-rich food ingredients (15 mg/100 g) in Southeast Asia) rather than increasing the portions of costly meat/fish components [14]. An alternative approach could be the provision of iron-fortified fish/soy sauce or the use of iron-fortified rice [15,16]. On the other hand, given the year-round availability and relatively low price for various vegetables and fruits in Cambodia, it should be straightforward to ensure an appropriate content of VitC, VitA, and folate in meals served to workers via staff canteens.

Although it is shown that a budget-priced lunch provision in garment factories is feasible, factory owners would face high operating costs throughout the year, besides the initial investment for setting up a large-scale canteen. A medium-sized Cambodian garment factory (about 1,000 employees) would need to raise several hundred thousand USD per year to operate a canteen for all employees. There are different actions that may encourage factory owners to make up their minds: the Cambodian government could support factory owners by providing tax incentives and buyers/brands could provide additional financial support by paying a higher remuneration per garment or directly subsidize daily lunch provision at factories via their corporate social responsibility (CSR) initiatives. Such a pilot CSR program including the operation of staff canteens in Cambodian garment factories has been funded by the UK retail giant Marks and Spencer [17].

The findings from chapter 4 have been obtained by multiple qualitative 24-h recalls using the established FAO guideline and questionnaire on assessing women's dietary diversity [18]. Although dietary diversity is positively associated with micronutrient adequacy [18], no information on the actual intake amount of macro- and micronutrients is provided by such a qualitative assessment. The implementation of quantitative dietary recalls was not feasible within the LUPROGAR study. Data collection was conducted during working hours and the time granted by the factory management for investigations was limited (about 0.5 h/subject). Moreover, garment workers had limited free time after working hours as well as during free days. In the end, using a rapid qualitative dietary recall was the only achievable approach to follow up the dietary intake of participants.

At baseline, study participants generally showed a relatively diverse 24-h dietary intake and their lunches represented the most diverse meal (compared to breakfast and dinner). However, the trial's model lunch provision was not specifically designed for improving the intake of specific underutilized foods nor the overall dietary diversity. Interestingly, although baseline 24-h consumption of iron-rich food items (flesh meats and fish) was common, the prevalence of poor iron status was high in subjects. In conclusion, the quantities of these rather expensive foods might have not been adequate to meet the RDA for iron as reported for Cambodian women [19]. Access to lunch provision was also significantly associated with a lower rate in lunch consumption of flesh meats, which is linked to the regular serving of fish in model lunch sets. Nonetheless, no differences were observed between the intervention and the control group for the 24-h dietary intake of flesh meats.

The rate of workers with home-prepared foods for lunch breaks in the intervention group expectedly dropped to 0% at follow-ups. Therefore, it is supposed that access to lunch provision results in saving time, money, and efforts on food preparation. In addition, it might also decrease the risk of lack of food safety as home-prepared lunch boxes are usually stored without cooling on factory grounds [20]. Significantly less intervention subjects reported purchasing of food/drinks during lunch breaks at follow-ups, which led to significantly lower spendings when compared to the control group (detailed data not shown). This fact leads to the conclusion that savings due to lunch provision considerably increase the disposable income among the women. Still, the proportion of workers in the intervention group purchasing additional food/drinks remained high

(about 60%), although LUPROGAR's lunch provision also included unlimited access to drinking water [2]. Intervention subjects mostly reported additional purchase of beverages and sweets after having visited the canteen. Nonetheless, lunch provision was associated with a distinctly lower intake of sweets, as sweets were not provided at the canteen, and a lower intake of free sugar among workers is generally regarded as beneficial [21]. Skipping of breakfast in intervention participants slightly increased. However, no significant difference in skipping breakfast between groups was observed at follow-ups. Consequently, skipping of meals in workers with access to a staff canteen should be closely monitored, as it might counteract the expected benefits from lunch provision. With increasing rates of women skipping breakfast, lunch programs for workers might need to consider an additional meal/snack provision in the morning.

Chapter 5 covers the interpretation of the impact of LUPROGAR's model lunch provision on anthropometry, Hb, and micronutrient status in study participants. Since similar trials among comparable populations are almost non-existent, valuable insights are provided for subsequent surveys, especially with respect to the observed effect sizes. The overall effects on anthropometric variables among – in their majority not underweight – garment workers are assumed to illustrate, if any, a very limited intervention impact on anthropometry. Ultimately, it remains unclear if any general effects on BMI and weight (despite being potentially small-sized) could be primarily linked to increased body fat mass (as represented by increased mean TSF) [22]. It also remains unresolved, if body fat-free mass (as represented by MUAMC) might be in truth affected [22]. However, the subgroup analysis prompts, among others, a more pronounced positive intervention impact on weight and BMI in underweight participants (BMI <18.5 kg/m^2) and those with a low-normal BMI (BMI ≥18.5 and <20 kg/m^2). These effects correspond to small to medium effect sizes (Cohen's d ≥0.2 and <0.5) [23], suggesting that the impact of lunch provision is closely related to the initial nutritional status of garment workers.

The recent International Labour Organization (ILO) multi-factory trial[g] reported that one year of food provision did not induce changes of the BMI of Cambodian garment workers [24]. However, due to the ILO trial's different study inclusion criteria, as well as the kind of food provision (ranging from snacks to full lunches), it is difficult to draw a comparison to the present study. The

[g] To the best of our knowledge, the only published study on food provision in garment factories.

impact from LUPROGAR's lunch provision on worker's anthropometry might have been mitigated by the frequent onset of infectious diseases among workers (see chapter 2), as infections are known to have an adverse effect on the nutritional status [25]. Therefore, lunch provision programs in garment factories might need to be accompanied by measures to prevent sicknesses among the employees. Furthermore, providing a free lunch to garment workers replaces lunch meals that are otherwise eaten by the women (see chapter 4). Thus, total dietary surplus (e.g. of calories) through lunch provision might be de facto restricted. Moreover, a distinct lower consumption of energy-dense sweets/sugared beverages was noted in intervention participants. Finally, although model lunch sets matched recommendations on the energy content [26], the RDA of 2115 kcal/day [27] might underestimate energy requirements of garment workers, particularly in those with a BMI <20 kg/m^2 and those exposed to heavy work load. For these workers, an adjusted higher amount of food energy during lunch provision might be needed.

Regarding the observed lower iron stores in intervention participants (which occurred especially in workers with sufficient iron stores at baseline (FER ≥50 µg/L)), the prevalence of poor iron status did not increase in the intervention group. Although data on the dietary iron intake of Cambodian garment workers are missing, the exemplary lunches could have contained less iron than lunches eaten by the workers in the absence of lunch provision. In addition, most of the dietary iron in the exemplary meals was provided as less bioavailable nonheme iron (see chapter 3). The enhancing effect of VitC on nonheme iron absorption might have been limited in a complete menu containing various components known to inhibit iron uptake [28,29].

It is believed that the overall finding in terms of the intervention effect on Hb concentration is not indicating a failure, as three out of four study subjects were not anemic at baseline. A positive impact on mean Hb concentration could not be expected among non-anemic participants. Still, the observed changes in mean Hb among intervention workers affected by moderate anemia are considered relevant. The prevalence of anemia in the study population was initially expected to be higher, since national data indicate that 45% of Cambodian women of reproductive age are anemic [9]. Iron deficiency can only partially explain anemia in this study population (see chapter 2). In a recent one-year randomized controlled trial, neither iron ingots added to cooking pots, nor daily iron supplements (18 mg/d) increased Hb concentration in anemic Cambodian women [30]. The contributors to the prevalence of anemia in Cambodia are debated actually and strategies to

improve zinc and folate status, as well as to treat and prevent hookworm infections, have been suggested [31]. Furthermore, genetic disorders (e.g. Hb E variants and α-thalassemia) contribute to the prevalence of lower Hb concentrations and an increased risk for anemia regardless of iron stores [31,32].

None of the study subjects were affected by frank VitA deficiency and only few participants showed a marginal VitA status at baseline. At the time of planning and given foregoing findings [33], the study population was expected to be more affected by a poor VitA status. As the uptake of VitA from the diet is under homeostatic control [34], no effects on mean RBP concentrations could be expected in VitA-replete intervention subjects, although the exemplary lunch sets were estimated to provide 66% of the RDA for retinol activity equivalent (RAE) on average (see chapter 3). The overall small-sized non-significant intervention effect on increasing RBP is largely based on the increase of mean RBP in few intervention subjects with marginal VitA deficiency, which is expected to be relevant, but confirmation of this effect is desirable in a larger study including more participants with suboptimal VitA status.

The finding on the intervention impact on mean folate concentration suggests that lunch sets provided a beneficial amount of dietary folate. Despite the fact that frank folate deficiency was not found among workers, the observed prevalence of marginal folate status is in line with previous reports that suggest measures to increase folate/folic acid intake of Cambodian women [31]. According to the subgroup analysis, the positive intervention effect on folate status not only concerned participants with marginal folate deficiency, but also subjects with adequate folate status. However, the increase in folate concentration among intervention subjects with marginal folate status can be partly attributed to the upregulation of folate uptake from the diet [35], as represented by the increase in mean folate in control participants with a marginal folate status.

Validity of the study

Table 2 outlines the several strengths of the LUPROGAR trial. An overall strength was the randomized controlled study design. External validity of the study was warranted, up to a certain degree, via the trial's setting and inclusion criteria [36]. Internal validity was ensured through the following procedures: informed consents, including a study description in lay language, were read to each participant prior to data collection; all data collection methods (questionnaires,

anthropometric measurements, blood sample collection etc.) were performed following written standard operating procedures and were pre-tested under field conditions; enumerators/assistants were intensively trained prior to data collection; regular quality control assessments were conducted; and data from the questionnaires and anthropometry sheets were double-entered [1–4].

Table 2. Strengths of the LUPROGAR study.

Characteristics	Details
Study design	- Randomized controlled trial
Setting	- Conditions of employment comparable to overall working conditions in the garment sector
Inclusion criteria	- Inclusion criteria represent a great part of workers employed by the garment sector - Clinical screening prior to enrollment
Intervention	- Feasible low-price model lunch provision with focus on acceptable Cambodian dishes - Lunch provision via established local caterer - Menu was slightly adjusted according to preferences expressed by workers in a short menu preference questionnaire - Canteen staff were instructed to serve constant portion sizes - Estimation of the nutritive value of model lunch sets considering the actual portion sizes - High acceptance among intervention group (women on average visited the canteen on 85% of intervention days)
Data collection	- Wide range of assessments
Ethical considerations	- Control participants received equal monetary compensation at the end of the trial - Anonymity of the collected data was assured

Further considerable strengths of the study were the design and the related implementation costs of the intervention tested (including the basic setup of the temporary canteen), setting LUPROGAR's model lunch provision as an example for operating a feasible and sensibly-priced staff canteen that could be adopted by factory owners. The temporary canteen was operated by an established local canteen provider and served lunch sets solely comprised local foods and common Cambodian dishes. A similar menu option would be offered by local canteen providers to factory owners interested in setting up a canteen on their factory premises. In addition, and despite the fact that access to the canteen was voluntary, the compliance and acceptance among interventions subjects in this trial was relatively high (women on average visited the canteen on 85% of intervention days).

Table 3 summarizes the limitations of the LUPROGAR trial. A main constraint was the exploratory character of the study. Except a small cross-sectional survey [10], data on the nutritional, Hb, and micronutrient status of Cambodian garment workers, as well as qualitative and quantitative dietary intake data, were missing at the time of study planning. To the best of our knowledge, no similar studies have been conducted before the implementation of the LUPROGAR trial. Consequently, it was not possible neither to estimate an appropriate intervention duration, nor to design the intervention in a gap-oriented manner specifically targeting underweight, anemia, micronutrient deficiencies, and/or dietary diversity. The recipes for the model lunch sets do not rest upon the trial's baseline findings [1], since most of the blood analyses had to be conducted abroad and the results were available months later.

The study included garment workers regardless of their initial nutritional, Hb, and/or micronutrient status. On the one hand, this approach reflects a real-life situation, as installed factory canteens would be accessible for all employees (including those being not underweight, not anemic, etc.). On the other hand, distinct positive effects from lunch provision can only be expected among malnourished individuals. An alternative approach would have been to include only workers affected by low BMI, low Hb, and/or specific micronutrient deficiencies. However, such a strategy would imply a purposeful gap-oriented intervention, requiring detailed quantitative dietary intake data.

Due to missing data on the nutritional status of Cambodian garment workers, together with non-existent exemplary data on the effects of similar interventions, no forehand information was accessible regarding the expected effect sizes. Nevertheless, it is believed that the explorative approach to estimate an appropriate sample for this trial is reasonable, being able to detect a small to medium standardized effect size of 0.35 (Cohen's *d*) between arms using a two-sided test (at a 5% level of significance and a statistical power of 80%) [23]. However, the number of subjects at endline was distinctly smaller than scheduled, limiting the statistical power and the effect sizes that could be measured. In general, the trial's sample size calculation was not suitable to examine very small to small effects. Moreover, the calculation of the sample size of studies such as the one reported here needs to consider the actual prevalence of malnutrition. The study considered multiple major outcomes, given the trial's explorative "pilot study" character [37] and no corrections for multiple comparisons have been made in general, which is in consistence with

recommendations for exploratory studies though [38]. Furthermore, given the high fluctuation rate, the endline assessment was conducted after five months, and not as planned after six months of lunch provision as initially planned.

Table 3. Limitations of the LUPROGAR study.

Characteristics	Details
Setting	- Purposely selected factory
Subjects	- No random preselection of participants
Sample size	- High fluctuation rate - Number of subjects smaller than targeted, limiting statistical power and effect sizes - Exploratory sample size calculation due to lack of reference data - Sample size not fully appropriate for the evaluation of frequencies of food group consumption - Small number of subjects in secondary subgroup analysis, not suitable for assessing specific effects on malnourished women
Outcomes	- Multiple outcomes given the exploratory trial design - No correction for multiple comparisons - Data on Vitamin B12 status of subjects missing at endline
Intervention	- Model lunch sets neither based on baseline findings, nor on any other gap-oriented assessment - Non-systematic sampling applied for the estimation of the nutritive value of lunches - Not specifically designed to improve the intake of specific foods or dietary diversity
Lack of data	At study planning: - No previous related trials - Missing data basis on appropriate intervention duration, as well as on amounts of calories or micronutrients to specifically target underweight, anemia, and/or micronutrient deficiencies - Missing information on effect sizes that could be anticipated At study implementation: - No quantitative dietary assessments among subjects - Prevalence of hemoglobinopathies and parasite infestations - Limited local food composition data (e.g. components known to inhibit iron uptake, folate data for some foods, data only available for fresh/raw status of foods)

Recommendations for stakeholders along the Cambodian garment sector

It is strongly recommended to develop and implement definite measures for improving the nutritional, Hb, micronutrient, and health status of young female garment workers in Cambodia. Any interventions aiming at lowering the prevalence of anemia should consider that inherited hemoglobin diseases are likely a contributing factor. Following the establishment of the national health insurance scheme for employees in 2017, stakeholders should closely monitor its effect on the prevalence of sicknesses and workers' tendency to continue working despite being sick. Considering the significant financial contribution of female garment workers to the social securing of their family households, improving national social and health systems, especially for low-income rural households, might be one option that could lead to increased disposable incomes and to improved nutrition among these women.

LUPROGAR's low-price model lunch provision demonstrated that the concept of staff canteens is feasible, relatively straightforward, and bears the potential to improve food security among garment workers, roughly at costs of less than 1 USD/person/day (at large scale). In order to support factory owners in the financing, the Cambodian government could support meal provision by providing tax incentives. Moreover, foreign buyers/brands could provide additional financial support. A positive impact on the nutritional status of workers, particularly in malnourished employees, might be more pronounced if lunch provision programs are simultaneously accompanied by measures to reduce the prevalence of sicknesses. Moreover, it is assumed that lunch provision via canteens, as an extra, is one opportunity to lower turnover rates and to increase employment duration among workers.

With regard to the configuration of lunch provision, affordable strategies are needed to increase the provision of iron in lunch meals. For example, lunches could incorporate some organ meats. In addition, a more gap-oriented design of the lunch provision, taking into account underutilized foods, is recommended for enhancing dietary diversity among workers. Skipping of meals of workers with access to a staff canteen should be closely monitored to avoid any unfavorable dietary changes.

Recommendations for subsequent research projects

Based on the relatively small sample size and the monocentric study design of the LUPROGAR trial, a larger multicenter survey among Cambodian garment workers is needed to verify the obtained baseline findings (i.e. prevalence rates of underweight, anemia, poor iron status, and sicknesses). Any subsequent nutrition-related study would benefit from reliable quantitative data on the dietary intake of workers. Ideally, such data collection would be accompanied by a survey on physical activity of garment workers, considering heavy work load and overtime work. Nevertheless, to obtain solid information on quantitative dietary intake, current Cambodian food composition tables need to be complemented as they are quite limited in the extent of analysis and the number of food items included.

Quantitative dietary intake data can then be used for a gap-oriented assessment, and the overall concept of meal provision can be optimized. By using these data, larger lunch provision trials should be conducted including specially designed meals adapted to the concrete needs of garment workers. Following studies could focus only on workers affected by underweight, anemia, or micronutrient deficiencies. On the other hand, a large multicentric study would also likely enroll a sufficient number of workers affected by these conditions. Given the overall very small to small-sized impact of lunch provision in the LUPROGAR study, subsequent trials could also consider a longer period of lunch provision. Finally, accompanying research should identify ways to increase the iron content and/or to increase the iron availability of model lunch sets. As not all anemias are linked to iron deficiency, the role of hemoglobinopathies, parasitic infections and folate/zinc status should be further elaborated.

Conclusions

Young female garment workers in Cambodia are identified as a part of the workforce with an elevated risk for nutritional deficiencies. Therefore, strategies need to be developed for improving their nutritional, Hb, micronutrient, and health status.

LUPROGAR's exemplary lunch sets for female garment workers matched recommendations regarding their contribution to RDA's of caloric content and macronutrient composition for sources of energy intake. However, the micronutrient content revealed a relatively low iron content in lunch sets. On the other hand, it is considered that model lunch sets contained beneficial and/or

adequate amounts of VitC, VitA, folate and VitB12, on average. Consequently, meal provision via staff canteens is expected to bear the potential to improve food security of workers, approximately at costs of less than 1 USD/person/day (at large scale). Furthermore, a more gap-oriented design of the lunch sets taking into account underutilized foods is recommended for increasing their dietary diversity. Skipping of meals among workers with access to a staff canteen should be closely monitored in order to avoid unfavorable dietary changes.

Although lunch provision through a canteen improves food security among workers, distinct positive effects on anthropometry, Hb, and micronutrient status, can solely be expected in malnourished individuals. It is suggested that similar, but larger trials including lunch sets adapted to defined needs of workers should be performed. The overall findings from this study should have a lot of practical implications for the design and implementation of subsequent studies, ongoing or planned lunch programs, and strategies aiming at the improvement of the nutritional and health status of female garment workers in Cambodia.

References

1. Makurat, J.; Friedrich, H.; Kuong, K.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Nutritional and micronutrient status of female workers in a garment factory in Cambodia. *Nutrients* **2016**, 8, 694.
2. Makurat, J.; Pillai, A.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Estimated nutritive value of low-price model lunch sets provided to garment workers in Cambodia. *Nutrients* **2017**, 9, 782.
3. Makurat, J.; Kretz, E.C.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Dietary diversity in Cambodian garment workers: the role of free lunch provision. *Nutrients* **2018**, 10, 1010.
4. Makurat, J.; Becker, N.; Wieringa, F.T.; Chamnan, C.; Krawinkel, M.B. Impact of lunch provision on anthropometry, hemoglobin, and micronutrient status of Cambodian garment workers: exploratory randomized controlled trial. *Unpublished manuscript* **2018**.
5. World Health Organization. *Physical Status: The Use and Interpretation of Anthropometry*: *Report of a WHO Expert Committee*; World Health Organization: Geneva, Switzerland, **1995**.
6. World Health Organization. *Iron Deficiency Anaemia. Assessment, Prevention, and Control*: *A guide for Programme Managers*; World Health Organization: Geneva, Switzerland, **2001**.
7. Milman, N. Iron in pregnancy: how do we secure an appropriate iron status in the mother and child? *Annals of Nutrition & Metabolism* **2011**, 59, 50–54.
8. Khan, M.R.; Ahmed, F. Physical status, nutrient intake and dietary pattern of adolescent female factory workers in urban Bangladesh. *Asia Pacific Journal of Clinical Nutrition* **2005**, 14, 19–26.
9. National Institute of Statistics; Directorate General for Health; ICF International. *Cambodia Demographic and Health Survey 2014*; National Institute of Statistics; Directorate General for Health; ICF International: Phnom Penh, Cambodia and Rockville, Maryland, USA, **2015**.
10. McMullen, A. *Shop`til They Drop. Fainting and Malnutrition in Garment Workers in Cambodia*; Labour Behind the Label & Community Legal Education Centre: Phnom Penh, Cambodia, **2013**.
11. International Labour Organization; World Bank. *Cambodia. Women and Work in the Garment Industry*; International Labour Organization: Phnom Penh, Cambodia, **2006**.

12. Kang, C.; Liv, D. *Living Wage Survey for Cambodia's Garment Industry*; Cambodia Institute of Development Study: Phnom Penh, Cambodia, **2009**.
13. International Labour Organization. *Cambodian Garment and Footwear Sector Bulletin. Issue 7. How has garment workers' pay changed in recent years?*; International Labour Organization: Phnom Penh, Cambodia, **2018**.
14. Kongkachuichai, R.; Napatthalung, P.; Charoensiri, R. Heme and nonheme iron content of animal products commonly consumed in Thailand. *Journal of Food Composition and Analysis* **2002**, 15, 389–398.
15. Laillou, A.; Pfanner, S.; Chan, T.; Chea, C.; Mam, B.; Sambath, P.; Vonthanak, S.; Wieringa, F. Beyond effectiveness-the adversities of implementing a fortification program. A case study on the quality of iron fortification of fish and soy sauce in Cambodia. *Nutrients* **2016**, 8, 94.
16. Muthayya, S.; Hall, J.; Bagriansky, J.; Sugimoto, J.; Gundry, D.; Matthias, D.; Prigge, S.; Hindle, P.; Moench-Pfanner, R.; Maberly, G. Rice fortification: an emerging opportunity to contribute to the elimination of vitamin and mineral deficiency worldwide. *Food and Nutrition Bulletin* **2012**, 33, 296–307.
17. Project HOPE. *HealthWorks Programme Report – Cambodia*; Project Hope: Millwood, Virginia, USA, **2015**.
18. Food and Agricultural Organization. *Guidelines for Measuring Household and Individual Dietary Diversity*; Food and Agricultural Organization: Rome, Italy, **2011**.
19. Wallace, L.J.; Summerlee, Alastair J S; Dewey, C.E.; Hak, C.; Hall, A.; Charles, C.V. Women's nutrient intakes and food-related knowledge in rural Kandal province, Cambodia. *Asia Pacific Journal of Clinical Nutrition* **2014**, 23, 263–271.
20. BDLINK; HRINC. *Study on the Perceptions of Garment Factory Owners on Nutrition and the Feasibility for Pursuing Canteen Services in the Garment Sector in Cambodia*; International Labour Organization: Phnom Penh, Cambodia, **2012**.
21. World Health Organization. *Guideline: Sugars Intake for Adults and Children*; World Health Organization: Geneva, Switzerland, **2015**.
22. Gibson Rosalind S. *Principles of Nutritional Assessment*; Oxford University Press: New York, New York, USA, **2005**.
23. Cohen, J. A power primer. *Psychological Bulletin* **1992**, 112, 155–159.
24. International Labour Organization. *Garment Workers' Health and Nutrition Status, and Food Provision in Factories. A Study from Selected Enterprises in Cambodia*; International Labour Organization: Phnom Penh, Cambodia, **2016**.
25. Krawinkel, M.B. Interaction of nutrition and infections globally: an overview. *Annals of Nutrition & Metabolism* **2012**, 61 (Suppl 1), 39–45.
26. German Nutrition Society (DGE). *DGE-Qualitätsstandard für die Betriebsverpflegung*; German Nutrition Society (DGE): Bonn, Germany, **2015**.
27. Barba, C.V.; Cabrera, M.I. Recommended dietary allowances harmonization in Southeast Asia. *Asia Pacific Journal of Clinical Nutrition* **2008**, 17 (Suppl 2), 405–408.
28. Collings, R.; Harvey, L.J.; Hooper, L.; Hurst, R.; Brown, T.J.; Ansett, J.; King, M.; Fairweather-Tait, S.J. The absorption of iron from whole diets: a systematic review. *The American Journal of Clinical Nutrition* **2013**, 98, 65–81.
29. Cook, J.D.; Reddy, M.B. Effect of ascorbic acid intake on nonheme-iron absorption from a complete diet. *The American Journal of Clinical Nutrition* **2001**, 73, 93–98.
30. Rappaport, A.I.; Whitfield, K.C.; Chapman, G.E.; Yada, R.Y.; Kheang, K.M.; Louise, J.; Summerlee, A.J.; Armstrong, G.R.; Green, T.J. Randomized controlled trial assessing the efficacy of a reusable

fish-shaped iron ingot to increase hemoglobin concentration in anemic, rural Cambodian women. *The American Journal of Clinical Nutrition* **2017**, 106, 667–674.
31. Wieringa, F.; Dahl, M.; Chamnan, C.; Poirot, E.; Kuong, K.; Sophonneary, P.; Sinuon, M.; Greuffeille, V.; Hong, R.; Berger, J.*; et al.* The high prevalence of anemia in Cambodian children and women cannot be satisfactorily explained by nutritional deficiencies or hemoglobin disorders. *Nutrients* **2016**, 8, 348.
32. Karakochuk, C.D.; Whitfield, K.C.; Barr, S.I.; Lamers, Y.; Devlin, A.M.; Vercauteren, S.M.; Kroeun, H.; Talukder, A.; McLean, J.; Green, T.J. Genetic hemoglobin disorders rather than iron deficiency are a major predictor of hemoglobin concentration in women of reproductive age in rural Prey Veng, Cambodia. *The Journal of Nutrition* **2015**, 145, 134–142.
33. Anderson, V.P.; Jack, S.; Monchy, D.; Hem, N.; Hok, P.; Bailey, K.B.; Gibson, R.S. Co-existing micronutrient deficiencies among stunted Cambodian infants and toddlers. *Asia Pacific Journal of Clinical Nutrition* **2008**, 17, 72–79.
34. Tanumihardjo, S.A.; Russell, R.M.; Stephensen, C.B.; Gannon, B.M.; Craft, N.E.; Haskell, M.J.; Lietz, G.; Schulze, K.; Raiten, D.J. Biomarkers of Nutrition for Development (BOND)-Vitamin A Review. *The Journal of Nutrition* **2016**, 146, 1816-48.
35. Said, H.M.; Chatterjee, N.; Haq, R.U.; Subramanian, V.S.; Ortiz, A.; Matherly, L.H.; Sirotnak, F.M.; Halsted, C.; Rubin, S.A. Adaptive regulation of intestinal folate uptake: effect of dietary folate deficiency. *American Journal of Physiology - Cell Physiology* **2000**, 279, 1889-95.
36. Rothwell, P.M. Factors that can affect the external validity of randomised controlled trials. *PLoS Clinical Trials* **2006**, 1, 9.
37. Eldridge, S.M.; Chan, C.L.; Campbell, M.J.; Bond, C.M.; Hopewell, S.; Thabane, L.; Lancaster, G.A. CONSORT 2010 statement: extension to randomised pilot and feasibility trials. *Pilot and Feasibility Studies* **2016**, 2, 64.
38. Bender, R.; Lange, S. Adjusting for multiple testing--when and how? *Journal of Clinical Epidemiology* **2001**, 54, 343–349.

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