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Efficacy of Technology-Assisted Personalized Nutrition Therapy in Managing Malnutrition Problems: A Systematic Review and Meta-Analysis of Clinical Trials

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ABSTRACT

Introduction: Malnutrition including obesity has long been an urgent health issue worldwide, but COVID-19 has put more challenges to its management. Aided with technology, personalized nutrition is a novel potential solution. Therefore, this paper aims to evaluate the efficacy of technology-assisted personalized nutrition therapy in managing nutrition problems.

Methods: We conducted literature screening through databases including PubMed, Scopus, Cochrane, ScienceDirect, EBSCOHost, and Google Scholar, searching for clinical trials implementing technology-assisted personalized nutrition therapy up to August 2021. Quality of studies were evaluated using the Cochrane Risk of Bias 2.0 tool and converted to AHRQ standards. We conducted qualitative extraction and quantitative analysis of mean differences using Review Manager 5.4 in inverse variance, random-effects model and whenever possible, subgroup and sensitivity analyses were performed.

Results: Our search yielded 9 studies with 5,173 participants. Technology-assisted personalized nutrition, delivered through web, mobile, or telephone-based approaches, is proven effective in improving anthropometric outcomes including weight (pooled MD: -0.82; 95%CI:-1.30—0.35; p=0.0007) and BMI of (pooled MD: -1.30; 95%CI:-1.97—0.62; p<0.00001) of the target participants. Improvements in dietary pattern is also significant as seen in better intakes of fruits and vegetables (pooled MD: 0.86; 95%CI:0.18-1.53; p=0.01), reduction of saturated fat and sweetened beverages, as well as general diet scores. Additionally, markers of inflammation, oxidative stress, total cholesterol, and blood glucose of participants also decreased significantly with the intervention.

Conclusion: Technology-assisted personalized nutrition is proven to be more effective compared to previous population-based intervention, thus supporting its potential use in clinical settings

KEYWORDS: Malnutrition, personalized, technology-assisted, nutrition therapy.

ARTICLE DETAILS

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INTRODUCTION

COVID-19 has brought tremendous changes in any sectors of life, from health, social, education, to economy. Social distancing is one of the most challenging yet unavoidable changes that result in reduced mobile, hence the increased rate of sedentary lifestyle.[1] Reports have identified the increased tendency of junk food consumption and less physical activity, which both leads to a malnutrition problem, that is increased body weight. Excess

body weight may lead to overweight and obesity. Statistics shows that over 13% of people worldwide suffers from obesity, while over 39% suffers from overweight. Although excess weight status have been correlated with developed countries, the trend has now shifted to

Developing countries as well.[1,2] Indonesia itself has also a rising prevalence of obesity. In fact, according to an observational study by Oddo et al, at least one-third of Indonesian adults are overweight.[3] These could lead to various harmful health effects, including risk of non-communicable diseases and more severe COVID-19.[1] Therefore, proportional body weight and healthy lifestyle are imperative to be implemented.

In this digital era, technological advancement is continuously evolving, accompanied by its increasing rate of usage, especially during the pandemic. The Ministry of Communication and Information Technology has reported that Indonesia smartphone ownership has reached 100 million,[4] accompanied by 82 million internet users.[5] Therefore,

Researchers have conducted studies on implementing the use of technology in observing weight-related problems and give health intervention digitally.

Meanwhile, personalized nutrition has been known to be beneficial for health, in that tailored dietary recommendation is given to an individual in consideration of the body response towards nutrition.[6] The aim of personalized nutrition is to give one maximum health outcomes, whilst minimizing unfavorable outcomes.[7] As the nutritional requirements are personalized to one's needs, the outcome is proven to be more efficient compared to the previous population-based intervention.[6]

Accordingly, digital personalized nutrition should be taken into consideration in managing these problems. To our knowledge, there has not been any published review yet, therefore, this paper aims to evaluate the efficiency of technology-assisted personalized nutrition types in managing malnutrition problems.

MATERIALS AND METHODS

Search strategy

This systematic review and meta-analysis follow the Cochrane Handbook for Systematic Reviews of Interventions 6.2 and reported according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA).[8,9] Literature search was conducted in multiple databases including PubMed, Cochrane, Google Scholar, Scopus, and Science Direct, searching for studies implementing technology-assisted personalized nutrition therapy up to August 23rd, 2021 with the following keywords: ("personalized" OR individualization OR individualized) AND ("Nutrition Therapy"[Mesh] OR "Diet Therapy"[Mesh] OR nutrition OR diet OR nourishment) AND (technology OR digital OR web-based) AND ("Malnutrition"[Mesh] OR malnutrition[Text Word] OR "Nutrition Disorders"[Mesh] OR "Obesity"[Mesh] OR "Overweight"[Mesh] OR "Thinness"[Mesh] OR underweight). Additional keywords are attached further in **Appendix 1**.

Study eligibility criteria

For study screening, the authors predetermined the following inclusion criteria: (1) type of study, clinical trials, randomised trials, controlled trials, and quasi experimental studies; (2) study population, healthy individuals or patients needing treatment, with no limitations to age, sex, baseline weight, or BMI; (3) intervention, technology-assisted personalized nutrition therapy; (4) outcomes, which include anthropometric changes, nutritional pattern changes, and other secondary parameters reported. Meanwhile, the exclusion criteria are set to: (1) unsuitable study design, including cohort studies, preclinical studies, commentaries, conference abstracts, and letters to the editor; (2) studies with incomplete outcome data; (3) studies with irretrievable full-text articles; (4) studies without a control group; and (5) studies in languages other than English.

Data extraction

We predetermined the outcome sheet in tabular form (MS Excel® for Mac; Microsoft Corporation, Redmond, WA, 2018) to include the following data to be extracted: (1) author and year of publication; (2) study characteristics, including study design and location of study; (3) study population, including sample size, characteristics of population, and mean age; (4) intervention, type of personalized technology-assisted method used and duration of study; as well as (5) study outcomes, including comparative indicators, value difference with and without intervention, and significance (p) values. Qualitative characteristics were extracted by two reviewers, and an independent third author rechecked accuracy of extracted data meanwhile performing statistical analysis.

Risk of bias assessment

Quality of each study were accessed using the Cochrane Risk of Bias 2.0,[10] which evaluates 5 domains such as bias due to randomisation, deviations from intended interventions, missing outcome data, outcome measurement, and reporting results. The overall bias is then converted based on the Agency for Healthcare Research and Quality (AHRQ) standards.

This assessment was performed by three independent reviewers and if there is any disagreement, resolution would be made based on consensus by the three reviewers.

Statistical analysis

Statistical analysis was performed using Review Manager ver. 5.4 (The Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen). We inputted mean differences and standard deviations (SDs) extracted from studies and evaluated the pooled effects. Considering that indecipherable heterogeneity could be discovered from studies, we utilised inverse variance, DerSimonian-Laird random effects model as proposed by Riley et al.[11] Heterogeneity was further evaluated using Cochran's Q test and I2 statistics, with cut-off limits of 0% as negligible, 25% as low, 50% as moderate, and 75% as high heterogeneity, respectively.[12] Whenever feasible, we performed subgroup analysis by intervention only or intervention and coaching in each study. Furthermore, when heterogeneity was found high, sensitivity analysis was performed using Duval and Tweedie's trim-and-fill analysis to identify any outlier study.[13]

RESULTS AND DISCUSSION

Search results and study selection

Initial search from PubMed, Scopus, Cochrane, Science Direct, EBSCOhost, and Google Scholar using previously mentioned strategy resulted in a total of 13,676 studies **(Figure 1**). Before the screening process, we exclude 35 studies which are either deduplicated, 11,752 studies which are marked as ineligible by automation tools, and 205 studies for other reasons, such as ineligible language. Furthermore, 1469 studies and 184 studies were excluded after title screening and abstract screening, respectively. Studies which are not related to our main topics are excluded in this phase. In addition, 21 studies were further excluded since 5 studies only measure qualitative outcomes, 6 studies use inappropriate intervention type, and 10 studies were not available in full text version. The final search yielded in a final nine studies, consisting of mostly randomized controlled trials to be included in further analysis.

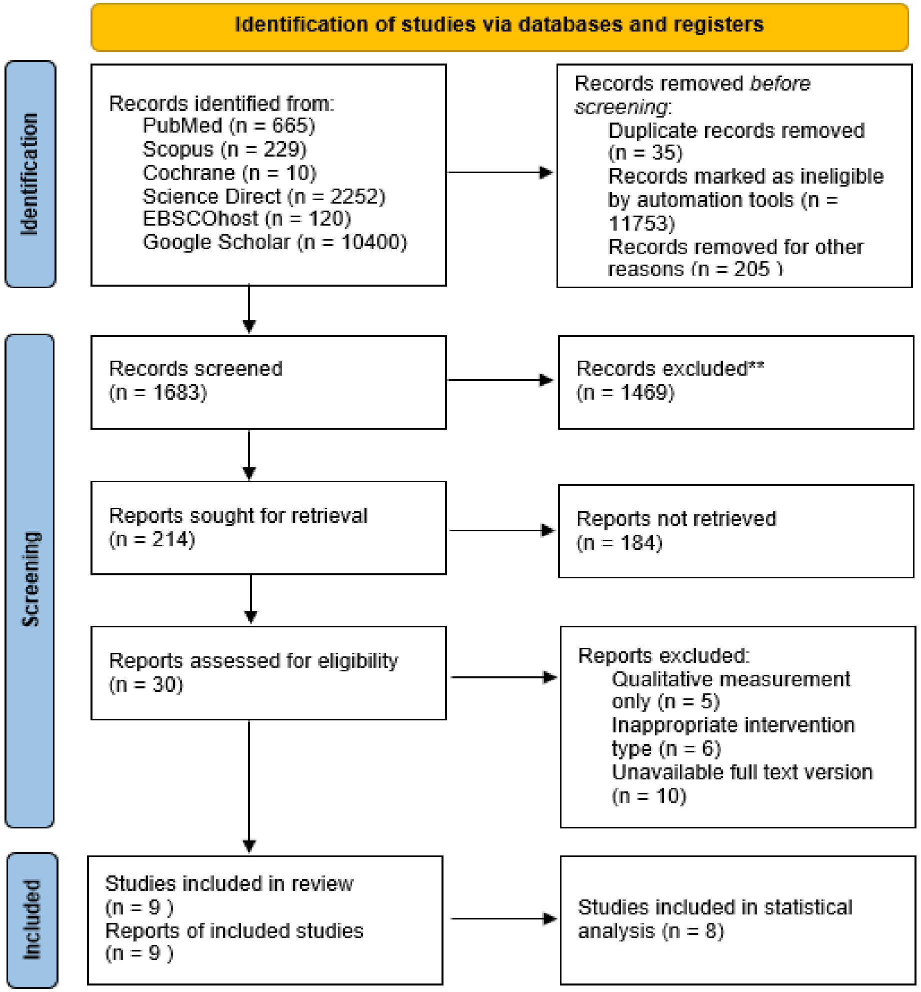


Figure 1. PRISMA diagram flow of literature search strategy.

Table 1 summarizes the characteristics of included studies. The search yielded 9 studies with a total of 5,173 subjects. The types of studies include 7 RCTs, 1 pilot randomized trial, and 1 quasi-experimental study. Location of studies is spread across the continents: 4 studies were conducted in Europe; 2 studies in Australia; 2 studies in USA; and 1 study was conducted in Asia. The publication year of studies included spans across 2013 up to 2021. The total sample size of these studies are 5173 participants; consisting of the control groups and intervention groups. Most patients had high baseline BMI and received technology-assisted personalized nutrition therapy via web-based, telephone-based, or mobile application-based approaches. Most of the studies are conducted on adults, however, two studies are performed in elderly participants, whereas one study by Bovi et al was performed on children.

Publication bias

Critical appraisal was conducted using Cochrane Risk of Bias 2.0 for randomized controlled trials criteria which were attached in the appendix section of this paper. This tool is used to evaluate the quality or bias of each study which is then categorized into low risk bias, some concerns, or high risk bias. Detailed descriptions of each domain are available on **Appendix 2**. From our systematic review and meta-analysis, we found no study with high risk of bias. Instead, three out of nine studies, that are studies by Valentini et al (2015), Rimmer et al (2013), and Bovi et al (2021), consider need of some concerns, while the rest are evaluated as having low risk of bias. However, those studies report need of concerns are only due to no information about the randomization process or bias in deviations from intended interventions because the participants are aware of their assigned interventions which is relatively unavoidable. Thus, most of the studies included in this review can be defined as having a good quality. Funnel plot is presented in Appendix 3.

Exploring novel concept of technology-assisted personalized nutrition

Personalized nutrition (PN) utilizes each individual's characteristics and information to create specialized nutritional advice which aim to change one's dietary behaviour to be healthier.[14] On the other hand, the rapid development of information and communication technology has made several activities more efficient, including for health management. Technology-assisted personalized nutrition is one of the most novel and promising findings. It utilizes mobile apps, telephones, or web-based intervention to deliver personalized nutrition advices to make it more efficient and convenient for the patients.[14]

Table 1. Characteristics of selected studies

Studies, year	Location	Study Design	Sample size	Characteristics	Mean age (SD)	Type of Intervention	Duration	Comparative Indicator	Value without Intervention	Value with Intervention	P-value
Valentini, 2015	France, Germany, Italy	Open label RCT	Diet alone/Arm A (n=31) Diet & VSL/Arm B (n=31)	Healthy individuals, BMI 22-30 kg/m2	70.1 ± 3.9 years	Web-based personalized dietary advice with complete individual recipes (RISTOMED platform) alone or with supplementation of VSL#3 bacterial blend	8 weeks	Weight change Decrease in hsCRP in subgroup with low-grade inflammation (hsCRP = 3-10 mg/l) Total cholesterol Blood glucose ESR	**Before RISTOMED only** -1.05 ± 1.89 1.42 ± 5.0 **Before RISTOMED only** 215 ± 7.5 94.5 ± 4.1 24.9 ± 3.4	**RISTOMED with VSL** -0.57 ± 1.5 0.28 ± 1.4 **After RISTOMED only** 202 ± 7.1 91.5 ± 3.9 18.9 ± 3.1	0.004/0.014 0.024 <0.01 0.03 0.02

Rollo, 2020	Australia	Pilot Randomized trial	Low personalization (n=24) High personalization (n=26)	Healthy individuals with BMI 26.4 ± 6.0 kg/m2, not pregnant, breastfeeding, or trying to conceive, stable weight (±4 kg) for the past 3 months, no dietary restrictions or medical conditions requiring intensive medical nutrition therapy	39.2 ± 12.5	Low personalization: personalized nutrition feedback report using the web-based Australian Eating Survey (AES) food frequency questionnaire High personalization: structured video calls, AES report, dietary self-monitoring with text message feedback	12 weeks	Australian Recommended Food Score (ARFS) Overall Change [Mean(95%CI)] %Intake from core (healthy, nutrient-dense) food %Intake from non-core (energy-dense, nutrient-poor) food %Participants that strongly agree or agree that the Australian Eating Survey was overall easy to use	**Low Personalization** -0.6 (-3.7-2.6) 4.5 (-0.3-9.3) -4.5(-9.3-0.3) 80.9	**High Personalization** 5.0 (2.1-8) 11.7 (7.2-16.2) -11.7 (-16.2--7.2) 81.8	0.01 0.04 0.04 N/A
Rimmer, 2013	USA	RCT	Total participant (n=102) POWERSplus intervention (n=22) Control (n=26)	Individuals with BMI 32.0 ± 5.8 kg/m2 with physical disability such as multiple sclerosis, spina bifida, spinal cord injury, cerebral palsy, stroke, o lupus	46.5 ± 12.7	Remote weight management program which is telephone-based and uses a web-based system: Personalized Online Weight and Exercise Response System and nutrition intervention (POWERSplus) OR control	9 months	Change in BMI B-PADS score Fat score change (higher scores indicate more frequent choosing of lower fat food) Fiber score change (higher scores indicate more frequent choosing of higher fiber food) Fruit/vegetable score	2.6 -1.8 0.1 0 0.1	-0.5 -1.6 0.2 0.2 0.2	N/A N/A N/A N/A N/A
Mamom, 2020	Thailand	RCT	Control (n=30) Experimental (n = 30)	Elderly bedridden patients with high risk of malnutrition	65.48 years old (SD = 6.26)	Self-required daily calorie intake using anti-malnutrition mobile application	48 weeks	Mean calories/day (kcal) Calories (administered-calculated) [kcal/day]	1540 ± 150 -50 ± 125	1530 ± 160 15 ± 110	N/A <.05

Livingstone, 2016	Ireland, Netherlands, Spain, Greece, United Kingdom, Poland, Germany	RCT	Total participant (n = 1607) Control (n = 387) Interventional (n = 120)	18 years old individuals (not pregnant or lactating, have adequate internet access, not in prescribed diet regiment, no metabolic diseases related to nutrition alteration)	39.9 ± 13.0 years old	Personalized dietary and physical activity advice on Food4Me website, based on: (L1) diet & PA; (L2) diet, PA & phenotypic data; (L3) diet, PA, phenotypic & genotypic data	24 weeks	MedDiet score at baseline MedDiet score at month 6 Fruit Vegetable	**Control Mean (L0)** 5.17 ± 0.09 5.20 ± 0.05 0.58 ± 0.01 0.60 ± 0.02	**Personalized Nutrition (mean L1, L2, L3)** 5.10 ± 0.05 5.48 ± 0.07 0.67 ± 0.02 0.62 ± 0.02	 0.49 0.002 0.001 0.47
Godino, 2019	United States	RCT	Total participant (n = 252) SMS (n = 85) SMS + coaching (n= 82) Control (n = 85)	21-60 years old, overweight (BMI 27.0 to 39.9 kg/m2), owner of cell phone capable of SMA, residing in San Diego county, English- and Spanish speaking adults	41.7 (11.1) years	ConTxt (Personalized SMS) only; ConTxt plus heath-coaching calls	48 weeks	Absolute weight change (6 months) Absolute weight change (12 months) BMI Change (6 months) BMI Change (12 months) Body fat percentage change (12 months) Absolute weight change (6 months) Absolute weight change (12 months) BMI Change (6 months) BMI Change (12 months) Body fat percentage change (12 months)	**Control** -1.25 (-2.52 to 0.03) -0.73 (-2.02 to 0.57) -0.31 (-0.73 to 0.11) 0.07 (-0.48 to 0.61) 0.18 (-0.64 to 1.00) **Control** -1.25 (-2.52 to 0.03) -0.73 (-2.02 to 0.57) -0.31 (-0.73 to 0.11) 0.07 (-0.48 to 0.61)	**SMS only** -2.12 (-3.47 to 0.88) -1.68 (-2.99 to -0.37) -0.51 (-0.94 to -0.09) -0.34 (-0.89 to 0.21) -0.44 (-1.26 to 0.39) **SMS plus Health Coaching Calls** -2.85 (-4.18 to -.152) -3.30 (-4.63 to -1.97) -.91 (-1.35 to -0.47) -.77 (-1.33 to -0.21)	 0.30 0.50 0.30 0.32 0.31 0.00 0.05 0.04 0.09

										0.18 (-0.64 to 1.00) **SMS Only** -2.18 (-3.47 to -0.88) -1.68 (-2.99 to -0.37) -0.51 (-0.94 to -0.09) -0.34 (-0.89 to 0.21) -.44 (-1.26 to 0.39)	-1.56 (-2.37 to -0.71) **SMS plus Health Coaching Calls** -2.85 (-4.18 to -1.52) -3.30 (-4.63 to -1.97) -.91 (-1.35 to -0.47) -.77 (-1.33 to -0.21) -1.56 (-2.37 to -0.71)	0.01 0.48 0.09 0.20 0.29 0.07
Celis-morales, 2016	Europe	RCT	Level 0 (Control) : 312 Level 1 : 312 Level 2 : 324 Level 3 : 321	Healthy participants from seven European countries; 46% were obese or overweight; 24% were centrally obese	Level 0: 39.4y (13.3) Level 1: 39.7y (12.9) Level 2: 40.2y (12.8) Level 3: 40.2y (13.1)	Platform only : 24-week behavior change program delivered using a web platform with personalized computer-delivered feedback Platform + coaching : same 24-week web-based behavior change program plus 12 weeks of personalized feedback delivered online by a dietitian Control/ waiting list : nonpersonalized dietary and physical activity recommendations delivered through	24 weeks		Healthy Eating Index (mean) Saturated fat (% total energy) Body weight BMI (kg.m^2) Waist circumference (cm)	51.8 14.6 84.6 28.9 100	53.1 13.5 83.9 28.6 99.2	0.010 <0.0001 0.128 0.097 0.173

						an e-booklet and videos					
Beleigoli, 2020	Australia	RCT	Total participant (n=1298) Control : 470 Platform only : 420 Platform + coaching : 408	University students and staffs with BMI of ≥25 kg/m2 and were not pregnant	Control : 33.4 (32.4-34.4) Platform only : 34.4 (33.4-35.6) Platform + coaching : 33.0 (31.9-34.0)	Platform only : 24-week behavior change program delivered using a web platform with personalized computer-delivered feedback) Platform plus coaching: same 24-week web-based behavior change program plus 12 weeks of personalized feedback delivered online by a dietitian; or waiting list (nonpersonalized dietary and physical activity recommendations delivered through an e-booklet and videos)	24 weeks	Weight change (kg)	–0.66 (–0.98 to –0.34)	Platform only : –1.08 (–1.41 to –0.75) Platform + coaching : –1.57 (–1.92 to –1.22)	0.001
								BMI change (kg/m^2)	–0.24 (–0.35 to –0.12)	Platform only : –0.38 (–0.50 to –0.26) Platform + coaching : –0.56 (–0.69 to –0.43)	0.001
								Vegetable intake change	–3 (–5 to 0)	Platform only : 3.0 (1 to 6) Platform + coaching : 5 (2 to 8)	0.001
								Sweetened beverage change	–6 (–12 to 0)	Platform only : 0 (–5 to 7) Platform + coaching : –14 (–21 to –8)	0.008
								Physical activity change	–14 (–28 to 0)	Platform only : 2 (–9 to 13) Platform + coaching :4 (–18 to 11)	0.19

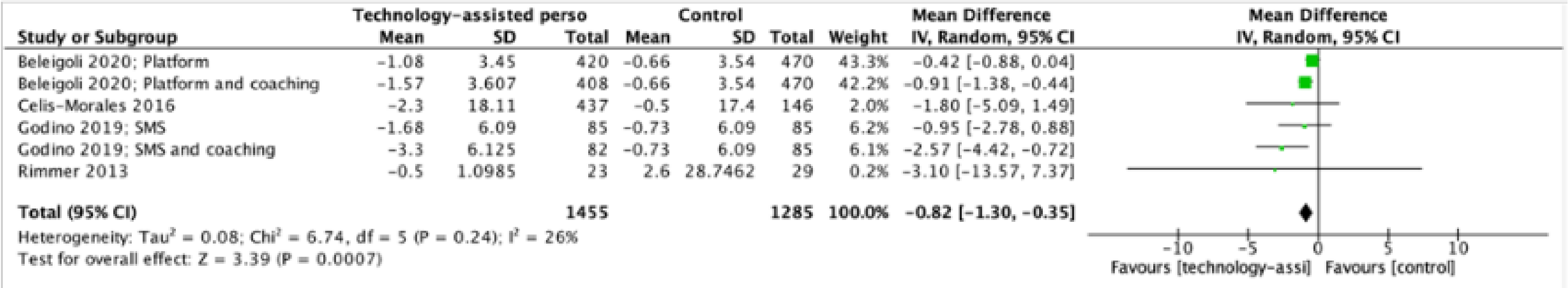
Bovi, 2021	Italy	Quasi-experimental (pilot)	Total participant: 103 children Control/ Pediafit 1.1 : 57%; Pediafit 1.2 : 66%	Children aged 6–14 years old, affected by obesity	Control group : 10.4y Interventio n group/ (Pediafit 1.2) : 9.7y	Messages, sent by a dedicated coach were inserted between three-monthly in-presence regular visits with (PediaFit 1.2) or without (PediaFit 1.1) monthly free-of charge short recall visits carried out by a specialized pediatric team.	6 months	**Adherence to follow-up** Regular visit at 6 months **Anthropometric parameters** BMI (Kg/m^2) Ex NC% Ex WC% **Lifestyle parameters** PA (min/week) F&V intake (portion/diet)	27 (90%) -4.6 (1.8) −57.18 (44.52) −34.19 (27.07) 112.2 (113.1) 2.57 (1.1)	3 (12%) 2.7 (2.8) −12.50 (17.67) −5.00 (7.07) 133.3 (23.09) 0.66 (1.15)	<0.0001 0.003 0.18 0.15 0.7 0.02

Anthropometric changes after technology-assisted personalized nutrition intervention: statistical and sensitivity analyses

Anthropometric changes have long been established as outcome measures in previous trials involving nutrition therapy since they are statistically quantifiable and measurable.[15] The basis for anthropometric improvements as the general outcome for nutritional interventions lies on the fact that these are associated with the occurrence of non-communicable diseases in both men and women.[16] In fact, each 5 kg/m^2 increase in BMI is associated with greater mortality with hazard ratio of 0.81 (95%CI:0.80-0.82) below 25 kg/m^2 and 1.21 (95%CI:1.20-1.22) above 25 kg/m^2. Moreover, studies have also shown that obese individuals have worse outcomes when infected with COVID-19 (OR=2.31; 95%CI:1.3-4.12).[17] Thus, it is essential in this study that improvement in anthropometric measurements including weight and BMI reduction become two of the primary outcomes of successful nutritional intervention.

The anthropometric outcomes evaluated in the studies included are demonstrated in **Figure 2** for weight change and **Figure 3** for BMI change, respectively. There are 6 studies included in the analysis for weight change in **Figure 2**, with pooled effect estimate showing favorable results (-0.82; 95%CI:-1.30—0.35) with assured significance (p=0.0007). The overall heterogeneity is low (I^2=26%), validating our results; however, when subgroup analysis is performed, moderate heterogeneity is found between studies that implement intervention and coaching (I^2=65%). Moreover, the pooled estimated mean difference for coaching in addition to intervention shows better outcomes (-1.49; 95%CI:-3.04-0.06) in comparison to the application of the technology-assisted personalized nutrition therapy only (-0.48; 95%CI:-0.92—0.04), but with small heterogeneity (I^2=33.4%) and no significant difference between subgroups (p>0.05).

A.



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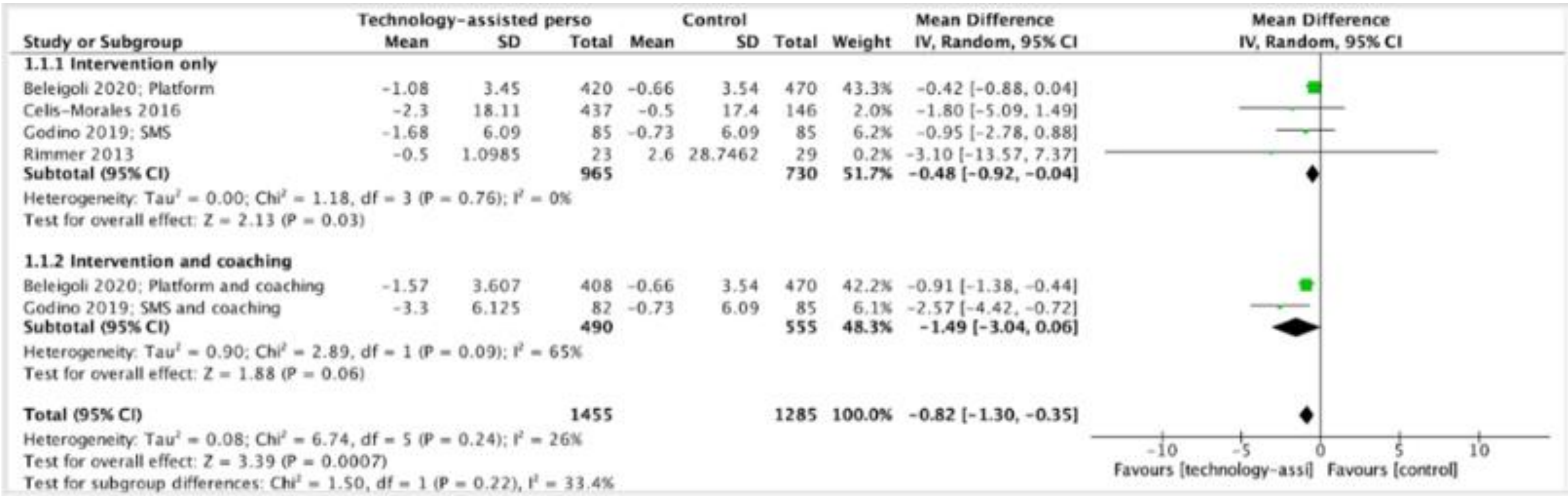


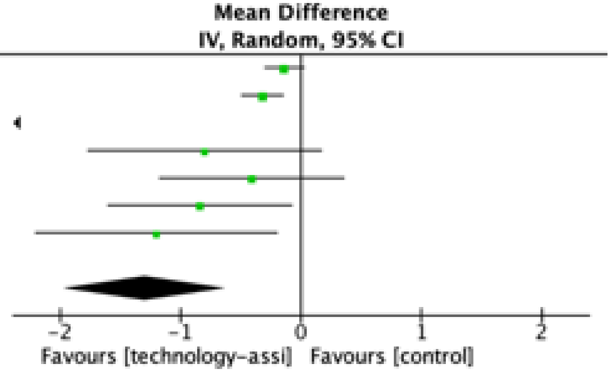
Figure 2. Forest plot showing (A) statistical analysis for weight change, (B) subgroup analysis.

Meanwhile, the outcomes on BMI is demonstrated in **Figure 3**, which also supports the benefits of technology-assisted personalized nutrition. With 7 studies included, overall effect estimate shows a pooled mean difference of -1.30 (95%CI:-1.97—0.62) which further establishes that technology-assisted personalized nutrition is superior to control in correcting BMI of its participants. Heterogeneity is found very substantial (I^2=95%), although the result is significant (p<0.00001). Furthermore, subgroup analysis was performed to investigate the differences between intervention only and intervention accompanied by coaching, and the latter is found more effective in regulating BMI outcomes (-0.46; 95%CI:-0.92-0.00 vs -2.74; 95%CI:-5.69-0.20). Between the subgroups, although the differences are not significant (p=0.13,>0.05), the heterogeneity is moderately found (I^2=55.3%).

A

Study or Subgroup	Technology-assisted perso Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Beleigoli 2020; Platform	−0.38	1.2511	420	−0.24	1.2136	470	17.4%	−0.14 [−0.30, 0.02]
Beleigoli 2020; Platform and coaching	−0.56	1.3358	408	−0.24	1.2136	470	17.4%	−0.32 [−0.49, −0.15]
Bovi 2021	−4.6	1.8	30	2.7	2.8	24	10.7%	−7.30 [−8.59, −6.01]
Celis-Morales 2016	−0.9	5.517	437	−0.1	5.025	146	13.0%	−0.80 [−1.77, 0.17]
Godino 2019; SMS	−0.34	2.5499	85	0.07	2.5035	85	14.4%	−0.41 [−1.17, 0.35]
Godino 2019; SMS and coaching	−0.77	2.5487	82	0.07	2.5035	85	14.4%	−0.84 [−1.61, −0.07]
Rimmer 2013	−0.2	1.2754	23	1	2.3553	29	12.7%	−1.20 [−2.20, −0.20]
Total (95% CI)			**1485**			**1309**	**100.0%**	**−1.30 [−1.97, −0.62]**

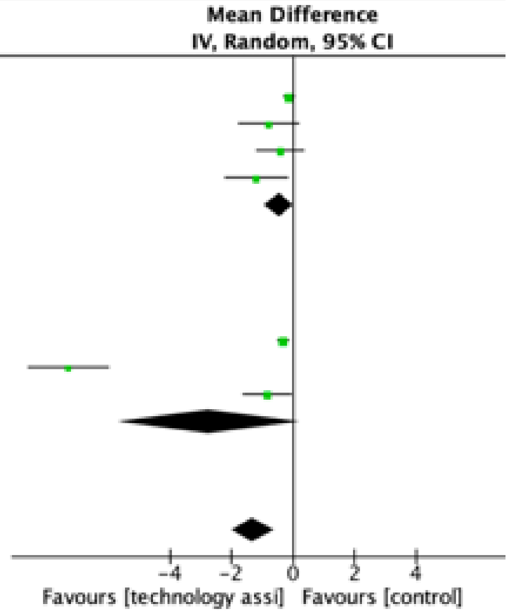
Heterogeneity: $Tau^2 = 0.67$; $Chi^2 = 122.53$, df = 6 ($P < 0.00001$); $I^2 = 95\%$
Test for overall effect: Z = 3.77 (P = 0.0002)



B

Study or Subgroup	Technology assisted perso Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
2.1.1 Intervention only								
Beleigoli 2020; Platform	−0.38	1.2511	420	−0.24	1.2136	470	17.5%	−0.14 [−0.30, 0.02]
Celis-Morales 2016	−0.9	5.517	437	−0.1	5.025	146	13.0%	−0.80 [−1.77, 0.17]
Godino 2019; SMS	−0.34	2.5499	85	0.07	2.5035	85	14.4%	−0.41 [−1.17, 0.35]
Rimmer 2013	−0.2	1.2754	23	1	2.3553	29	12.7%	−1.20 [−2.20, −0.20]
Subtotal (95% CI)			**965**			**730**	**57.5%**	**−0.46 [−0.93, 0.00]**
Heterogeneity: $Tau^2 = 0.11$; $Chi^2 = 6.11$, df = 3 (P = 0.11); $I^2 = 51\%$								
Test for overall effect: Z = 1.95 (P = 0.05)								
2.1.2 Intervention and coaching								
Beleigoli 2020; Platform and coaching	−0.56	1.3358	408	−0.24	1.2136	470	17.4%	−0.32 [−0.49, −0.15]
Bovi 2021	−4.6	1.8	30	2.7	2.8	24	10.7%	−7.30 [−8.59, −6.01]
Godino 2019; SMS and coaching	−0.77	2.5487	82	0.07	2.5499	85	14.3%	−0.84 [−1.61, −0.07]
Subtotal (95% CI)			**520**			**579**	**42.5%**	**−2.74 [−5.69, 0.20]**
Heterogeneity: $Tau^2 = 6.58$; $Chi^2 = 111.17$, df = 2 ($P < 0.00001$); $I^2 = 98\%$								
Test for overall effect: Z = 1.82 (P = 0.07)								
Total (95% CI)			**1485**			**1309**	**100.0%**	**−1.30 [−1.97, −0.62]**

Heterogeneity: $Tau^2 = 0.67$; $Chi^2 = 122.50$, df = 6 ($P < 0.00001$); $I^2 = 95\%$
Test for overall effect: Z = 3.77 (P = 0.0002)
Test for subgroup differences: $Chi^2 = 2.24$, df = 1 (P = 0.13), $I^2 = 55.3\%$



C

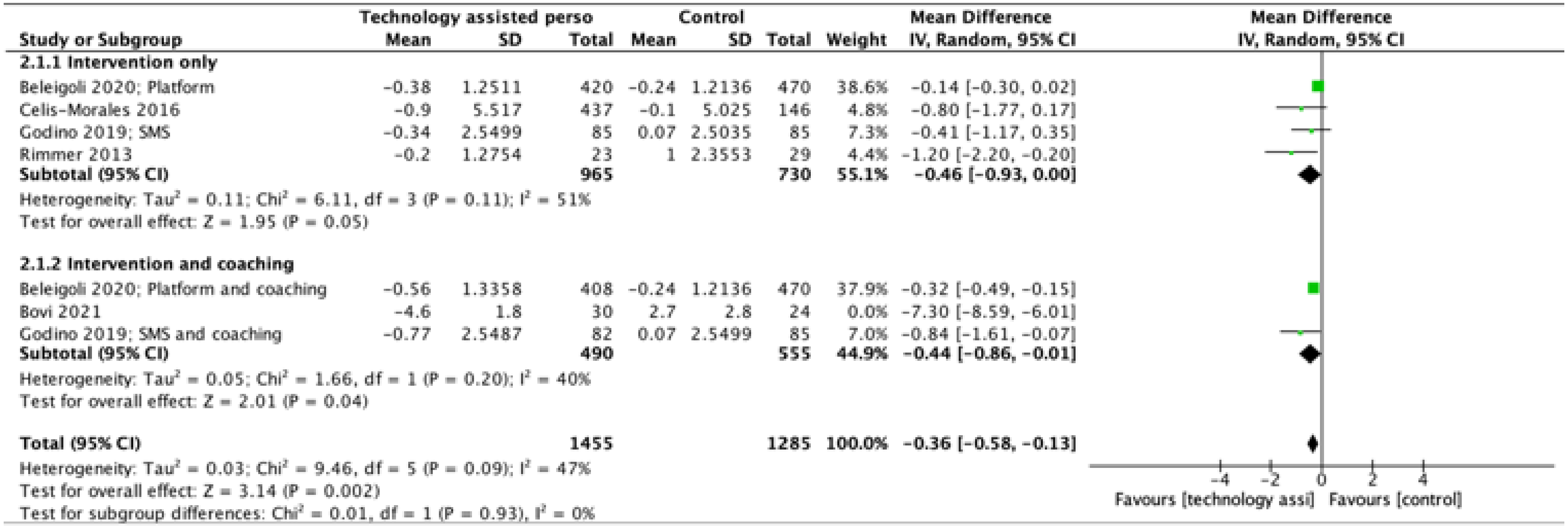


Figure 3. Forest plot showing (A) statistical analysis for BMI change, (B) subgroup analysis, and (C) sensitivity analysis based on subgroups.

Moreover, when we performed sensitivity analysis in exploring the high heterogeneity especially in the intervention and coaching subgroup, we found that Bovi et al's study is an outlier, with the heterogeneity yielding a much lower I^2 value of 40% in the subgroup and 47% overall after its removal. The explanation for this outcome might be that Bovi et al's study is a quasi-experimental study with two main approaches, PediaFit 1.1 with 3 regular visits and 3 messages each week, or PediaFit 1.2 with additional 4 on-site recall visits. The variable intervention thus may have contributed to the heterogeneity of this study. In addition, Bovi et al study is the only one who performed their experiment in children.

Fruits and vegetables as primary improvement in nutritional intake habits: statistical and sensitivity analysis

Fruits and vegetables intake are regarded as the most prominent improvement in nutritional intake.[18] In fact, a meta-analysis by Aune et al has further affirmed the strength of fruits and vegetables intake in reducing risks of cardiovascular diseases (RR per 200g/day: 0.97; 95%CI: 0.95-0.99) and cancer (0.97; 95%CI: 0.95-0.99), as well as mortality in general (0.9; 95%CI: 0.87-0.93).[19] Moreover, this effect is achieved in a dose-response relationship, with better outcomes with each 200g/day increase in intake.

Figure 4 shows additionally favorable results of technology assisted personalized nutrition intervention in enhancing diet patterns, as shown by the improvement by estimated pooled mean difference of 0.86 (95%CI:0.18-1.53) and significant test for effect (p=0.01). In this case, we did not perform a subgroup analysis since there is only one study implementing both platform and coaching and thus heterogeneity in-between studies wouldn't be yielded. In order to explore the high heterogeneity (I^2=90%), we thus performed a follow-up sensitivity analysis.

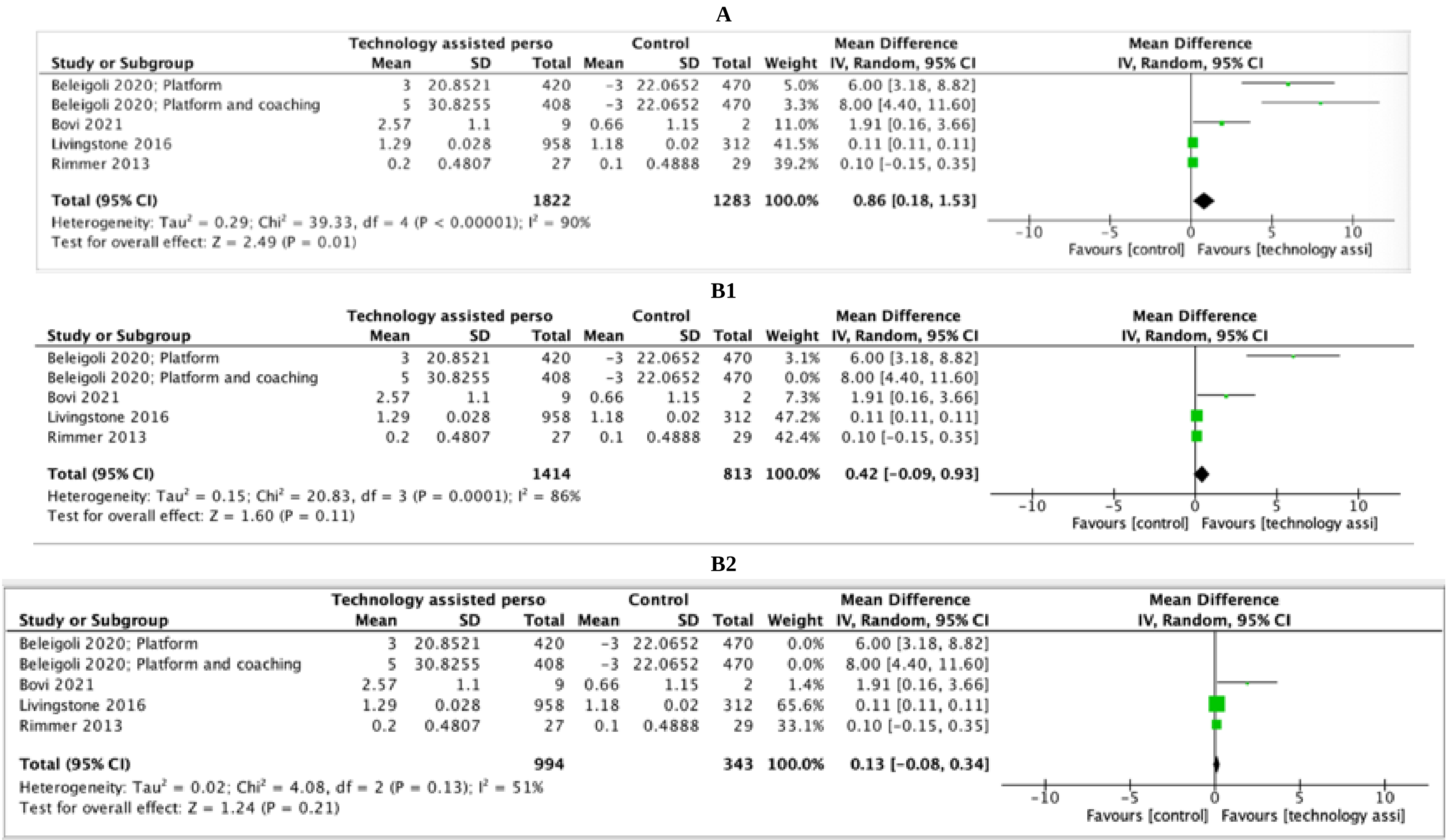


Figure 4. Forest plot showing (A) statistical analysis for fruits and vegetables intake and (B1 and B2) sensitivity analysis.

From the trim-and-fill method, after removal of both platform and platform and coaching outcome data from Beleigoli et al's study, we found rapid decrease in heterogeneity, identifying it as an outlier (I^2=51%). The reason for this might be due to the measures used for food, which is the Brazilian food frequency questionnaire reported after 24 weeks. Despite the large number of participants, one-time self-reporting of food may introduce heterogeneity since some participants may not accurately fill in the questionnaire.

Effectiveness in secondary changes of nutritional intake

Study by Rimmer et al (2013) assess the fat and fiber score change, which describe the proactive action of substituting their foods with lower portion of fat and higher portion of fibery foods.[20] Participants who were given online weight management program has greater habitual change. Other studies by Celis-Morales et al (2016) and Livingstone et al (2016) also reported significantly less consumption of red meat (p=0.046) and saturated fat

($p<0.0001$). Furthermore, the same study reported significantly lower intake of salty foods ($p=0.002$) in participants which were given personalized nutritional (PN) advices.[21,22] Meanwhile, study by Beleigoli et al (2020) found that sweetened beverages consumption lower significantly ($p=0.008$).[23] Other parameters, such as mean calories intake per day are also found to be lower although not as significant as previous parameters.[24] Several studies by Rollo et al (2020), Livingstone et al (2016), Celis-Morales (2016) measured nutritional intake with specialized questionnaire, namely Australian Recommended Food Score (ARFS), Healthy Eating Index (HEI), or MedDiet, respectively. All of the results have shown significant score change between intervention and control group.[14,21,22]

Other measured outcomes

Other outcomes were also measured, such as Valentini et al (2015) who measured blood and stool samples to search for glucose and cholesterol level, and the erythrocyte sedimentation rate (ESR).[25] Total cholesterol and blood glucose in patients which were given personalized diet plan decreased significantly ($p<0.01$ and $p=0.03$ respectively). Moreover, ESR, which can be related to inflammation process in the body, was also found to be significantly decrease ($p=0.02$).

Physical activity changes were also assessed by Rimmer et al (2013), Beleigoli et al (2020), and Bovi et al (2021) using slightly different method or questionnaire.[20,23,26] However, there are no significant differences of physical activity duration or frequency in both intervention and control group ($p>0.05$). Lastly, adherence to follow-up, which was evaluated as regular visit at 6 months by Bovi et al (2021) resulted in significant higher adherence in the intervention group ($p<0.0001$).[26]

Strengths and limitations

To our knowledge, this is the first systematic review and meta-analysis to assess the effectiveness of digital personalized nutrition in managing nutritional intake and healthy lifestyle. Our meta-analysis yielded a significant pooled mean difference and was statistically significant. Most of the studies included in this review is randomized controlled trials, the prime type of study in assessing efficacy of an intervention. However, the limitation of our study was the high heterogeneity from the meta-analysis, that may be caused by the wide variation of interventions given, such as personalized nutrition only or with additional coaching session. Furthermore, this review was only reviewed from studies written in English.

CONCLUSION AND RECOMMENDATION

Increased sedentary lifestyle and change in dietary habit during the COVID-19 pandemic have resulted in more malnutrition problems worldwide. Personalized nutrition has been proven to be efficient in managing malnutrition problems, proven by favourable anthropometric and nutritional changes. Amongst the outcomes of this service, improved BMI status, fruit and vegetable intake; as well as reduced fatty and salty food intake, and sweetened beverages intake are a few of favourable results obtained from personalized nutrition service. In addition, total cholesterol and blood glucose level were also proven to decreased significantly. Furthermore, we propose recommendation that digital personalized nutrition to be clinically applied, in solving malnutrition problems. However, further studies are needed to prove the cost effectiveness of digital personalized nutrition in managing malnutrition problems.

REFERENCES

I. Chew HSJ, Lopez V. Global Impact of COVID-19 on Weight and Weight-Related Behaviors in the Adult Population: A Scoping Review. Int J Environ Res Public Health. 2021 Feb 15;18(4):1876.

II. Bhurosy T, Jeewon R. Overweight and obesity epidemic in developing countries: a problem with diet, physical activity, or socioeconomic status? ScientificWorldJournal. 2014;2014:964236.

III. Oddo VM, Maehara M, Rah JH. Overweight in Indonesia: an observational study of trends and risk factors among adults and children. BMJ Open. 2019 Sep 1;9(9):e031198.

IV. KOMINFO P. Indonesia Raksasa Teknologi Digital Asia [Internet]. Website Resmi Kementerian Komunikasi dan Informatika RI. [cited 2021 Aug 30]. Available from: http:///content/detail/6095/indonesia-raksasa-teknologi-digital-asia/0/sorotan_media

V. Kementerian Komunikasi dan Informatika [Internet]. [cited 2021 Aug 30]. Available from: https://kominfo.go.id/index.php/content/detail/3980/Kemkominfo%3A+Pengguna+Internet+di+Indonesia+Capai+82+Juta/0/berita_satker

VI. Verma M, Hontecillas R, Tubau-Juni N, Abedi V, Bassaganya-Riera J. Challenges in Personalized Nutrition and Health. Front Nutr. 2018 Nov 29;5:117.

VII. Ordovas JM, Ferguson LR, Tai ES, Mathers JC. Personalised nutrition and health. BMJ. 2018 Jun 13;361:bmj.k2173.

VIII. Higgins J, Thomas J, editors. Cochrane Handbook for Systematic Reviews of Interventions [Internet]. 6.2. Cochrane Training; [cited 2021 Aug 25]. Available from: https://training.cochrane.org/handbook/current

IX. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ. 2009 Jul 21;339:b2535.

X. Risk of Bias 2 (RoB 2) tool [Internet]. [cited 2021 Aug 25]. Available from: https://methods.cochrane.org/risk-bias-2

XI. Riley RD, Moons KGM, Snell KIE, Ensor J, Hooft L, Altman DG, et al. A guide to systematic review and meta-analysis of prognostic factor studies. BMJ. 2019 Jan 30;364:k4597.

XII. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ. 2003 Sep 6;327(7414):557–60.

XIII. Duval S, Tweedie R. Trim and fill: A simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. Biometrics. 2000 Jun;56(2):455–63.

XIV. Rollo ME, Haslam RL, Collins CE. Impact on dietary intake of two levels of technology-assisted personalized nutrition: A randomized trial. Nutrients. 2020;

XV. Verreijen AM, Engberink MF, Memelink RG, van der Plas SE, Visser M, Weijs PJM. Effect of a high protein diet and/or resistance exercise on the preservation of fat free mass during weight loss in overweight and obese older adults: a randomized controlled trial. Nutr J. 2017 Feb 6;16(1):10.

XVI. Censin JC, Peters SAE, Bovijn J, Ferreira T, Pulit SL, Mägi R, et al. Causal relationships between obesity and the leading causes of death in women and men. PLoS Genet. 2019 Oct;15(10):e1008405.

XVII. Yang J, Hu J, Zhu C. Obesity aggravates COVID-19: A systematic review and meta-analysis. J Med Virol. 2021 Jan;93(1):257–61.

XVIII. Głąbska D, Guzek D, Groele B, Gutkowska K. Fruit and Vegetable Intake and Mental Health in Adults: A Systematic Review. Nutrients. 2020 Jan 1;12(1):E115.

XIX. Aune D, Giovannucci E, Boffetta P, Fadnes LT, Keum N, Norat T, et al. Fruit and vegetable intake and the risk of cardiovascular disease, total cancer and all-cause mortality-a systematic review and dose-response meta-analysis of prospective studies. Int J Epidemiol. 2017 Jun 1;46(3):1029–56.

XX. Rimmer JH, Wang E, Pellegrini CA, Lullo C, Gerber BS. Telehealth weight management intervention for adults with physical disabilities: A randomized controlled trial. American Journal of Physical Medicine and Rehabilitation. 2013;

XXI. Livingstone KM, Celis-Morales C, Navas-Carretero S, San-Cristoba R, MacReady AL, Fallaize R, et al. Effect of an Internet-based, personalized nutrition randomized trial on dietary changes associated with the Mediterranean diet: The Food4Me Study. American Journal of Clinical Nutrition. 2016;

XXII. Celis-Morales C, Livingstone KM, Marsaux CFM, Macready AL, Fallaize R, O'Donovan CB, et al. Effect of personalized nutrition on health-related behaviour change: Evidence from the Food4Me European randomized controlled trial. International Journal of Epidemiology. 2017;46(2):578–88.

XXIII. Beleigoli A, Andrade AQ, Diniz MDF, Ribeiro AL. Personalized web-based weight loss behavior change program with and without dietitian online coaching for adults with overweight and obesity: randomized controlled trial. Journal of Medical Internet Research. 2020;22(11):1–13.

XXIV. Mamom J. Digital Technology : Innovation for Malnutrition Prevention among Bedridden Elderly Patients Receiving Home-Based Palliative Care. 2020;47(10).

XXV. Valentini L, Pinto A, Bourdel-Marchasson I, Ostan R, Brigidi P, Turroni S, et al. Impact of personalized diet and probiotic supplementation on inflammation, nutritional parameters and intestinal microbiota - The 'RISTOMED project': Randomized controlled trial in healthy older people. Clinical Nutrition. 2015;

XXVI. Bovi APD, Cesari GM, Rocco MC, Di Michele L, Rimauro I, Lugiero A, et al. Healthy lifestyle management of pediatric obesity with a hybrid system of customized mobile technology: The pediafit pilot project. Nutrients. 2021;13(2):1–15.