Supplementary Table 1. Search strategy

Search category	Search terms
Virtual assistant	"chatbot*" OR "chat bot" OR "chat-bot" OR "chatter bot" OR "chatterbot" OR "chatter robot" OR "artificial intelligence" OR "virtual agent" OR "bot" OR "conversational bot*" OR "conversational agent*" OR "conversational system*" OR "conversational interface" OR "conversational AI" OR "conversational agency" OR "dialog system*" OR "dialogue system*" OR "assistance technolog*" OR "relational agent*" OR "virtual agent*" OR "virtual assistant*" OR "virtual coach"
Health behaviours	Physical activity: "physical activit*" OR "exercise" OR "exercis*" OR "sport*" OR "MVPA" OR "walk*" OR "health behav*" OR "behavior change" OR behaviour change" OR "physical training" OR "outdoor activity" OR "fitness" OR "strength exercise" OR "resistance training" OR "weight-lifting" OR "weight lifting" OR "bicycle*" OR "cycl*" OR "swim*" OR "run*" or "jog*" OR "play*" OR "lifestyle" Sedentary behaviour: "sedentary lifestyle" OR "sedentar*" OR "sitting" OR "screen time" OR "inactiv*" OR "television" OR "TV" OR "Video games" OR "video gam*" OR "health promotion" OR "health behav*" OR "behav* change" Sleep: "sleep" OR "insomnia" Diet/nutrition: "diet" OR "nutrition*" OR "healthy eating" OR "food habits" OR "fruit" OR "vegetable" OR "snack food*" OR "snack*" OR "soft drink*" OR "carbonated beverages" OR "discretionary food*" OR "junk food*" OR "eat*" OR "weight*" OR "overweight" OR "over-weight" OR "obesity" OR "bodyweight" OR "body composition*" OR "BMI" OR "body mass index"

Supplementary Table 2. Study quality ratings and risk of bias assessed using the Effective Public Heath Practice Project Quality Assessment Tool.

Study	Selection Bias	Study Design	Confounders	Blinding	Data Collection Methods	Withdrawals and Dropouts	Overall Rating*
Bickmore 2013A	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong
Bickmore 2013B	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Carlin 2021	Weak	Strong	Weak	Weak	Strong	Moderate	Weak
Carfora 2019	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Cushing 2021	Weak	Strong	Strong	Weak	Strong	Strong	Weak
De-Jongh González 2022	Moderate	Strong	Weak	Weak	Strong	Strong	Weak
Dhinagaran 2021	Weak	Moderate	Strong	Weak	Strong	Strong	Weak
Friederichs 2014	Weak	Strong	Weak	Weak	Strong	Weak	Weak
Gardiner 2017	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Hassoon 2021	Moderate	Strong	Strong	Weak	Strong	Strong	Moderate
King 2007	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Kramer 2020	Weak	Moderate	Strong	Weak	Strong	Strong	Weak
Lorenz 2019	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Maher 2020	Moderate	Moderate	Strong	Weak	Strong	Strong	Moderate
Phillip 2022	Weak	Strong	Strong	Weak	Strong	Weak	Weak
To 2021	Moderate	Moderate	Strong	Weak	Strong	Moderate	Moderate
Watson 2012	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Werner-Seidler 2019	Weak	Moderate	Strong	Weak	Strong	Moderate	Weak
Wright 2013	Moderate	Strong	Strong	Weak	Strong	Strong	Moderate

∗Strong overall rating = 0 weak sub-ratings; moderate overall rating =1 weak sub-ratings; weak overall rating = ≥2 weak sub-ratings.

Supplementary Table 3. Study and sample characteristics.

Author, year, country	Study design, length	Sample size and participants	Age, mean (SD)	Gender (n, % female)	Outcomes	Adverse events
Bickmore, 2013, USA	RCT, 12 m	n=263 older adults aged 65+	71.3 (5.4)	n=161 (61.2%)	Physical activity (International Physical Activity Questionnaire, Steps walked: Omron HJ-720ITC pedometers Dietary behaviour (NIH/NCI Fruit and Vegetable Scan)	n=289 adverse events (n=8 control and n=2 intervention, mild- to moderate-severity events related to participation in the study)
Bickmore 2013B, USA	RCT, 8 w	n=122 adults	Activity: 33.5 (12.8) Diet: 32.9 (11.1) Activity+Diet: 32.4 (12.3) Control: 32.0 (14.5)	Activity: 16 (51.6%) Diet: 17 (56.6%) Activity+Diet: 22 (73.3%) Control: 19 (61.3%)	Physical activity (steps, pedometer) Dietary behaviour (NIH/NCI Fruit and Vegetable Scan)	None
Carfora, 2019, Italy	Panel design, 2 w	n=180 young adults	20 (2)	n=136 (76%)	Red and processed meat consumption (food diary)	None
Carlin, 2021, United Kingdom	RCT, 12 w	n=25 families, with at least one child aged 5-12 years	Phase 1: Parents: 40.5 (5.4); Children: 9.1 (2.0) Phase 2: Parents: 38.9 (5.2); Children: 7.9 (2.0)	Phase 1: Parents: 10 (91%); Children: 9 (56%) Phase 2: Parents: 11 (73%); Children: 8 (44%)	Physical activity (ActiGraph GT3 accelerometer)	None
Cushing, 2021, USA	Non-RT, 20 d	n=40 adolescents aged 13-18	Intervention: 15.25 (1.80) Control: 15.25 (1.62)	Intervention: 15 (75%) Control: 15 (75%)	Physical activity (ActiGraph wGT3X-BT)	None
De-Jongh González, 2022, Canada	RCT, 12 w	n=214 parent-child dyads	Parents: 44 (SD); children: 13 (SD 2.2)	Children: n=110 (51.4%)	Dietary behaviour (Waterloo Eating Behavior Questionnaire and the Canadian healthy Heating Index used as a measure of overall adherence to the 2007 Canada's Food Guide) Physical activity (Fitbit Flex 2, Physical Activity Questionnaire Short Form)	None
Dhinagaran, 2021, Singapore	Pre-post, 4 w	n=60 adults	33.7 (9.3)	n=37 (62%)	Physical activity (International Physical Activity Questionnaire) Sleep (Pittsburgh Sleep Quality Index)	None
Friederichs, 2014, Netherlands	RCT, 4 w	n=958 adults 18-70 years old	42.9 (14.5)	n=579 (60.4%)	Physical activity (Dutch Short Questionnaire to Assess Health Enhancing Physical Activity (SQUASH))	None
Gardiner, 2017, USA	RCT, 30 d	n=61 women aged 18-50	Intervention: 33 (8.1) Control: 37 (8.4)	Overall: n=61 (100%)	Dietary behaviour (National Health and Nutrition Examination Survey (NHANES)) Physical activity (Stanford Patient Education Research Centre's Exercise Behaviours Questionnaire)	None
Hassoon, 2021, USA	RCT, 4 w	n=45 adult cancer survivors	My Coach: 63.9 (9.3) Smart Text: 64.1 (7.2) Control: 58.1 (11.8)	My Coach: n=14 (100%) Smart Text: n=11 (79%) Control: n=13 (93%)	Physical activity (Steps, Objectively assessed)	None

King 2007, USA	RCT, 12 m	n=75 inactive adults aged 55+	Human intervention: 60.5 (6.0) Automated intervention: 61.6 (5.9) Control: 60.2 (4.5)	Human advice intervention: n=47 (70.5%) Automated advice intervention: n=43 (69.7%) Control: n=42 (67.7%)	Physical activity (Stanford 7-day physical activity recall)	None
Kramer, 2020, Switzerland	Pre-post, 6 w	n=274 members of a health insurance company	41.73 (13.54)	n=158 (57.66%)	Physical activity (Steps, smartphone app)	None
Lorenz 2019, Germany	RCT, 6 w	n=56 adults aged 18+ with insomnia	Intervention: 41.72 (17.31) Control: 44.04 (20.05)	Intervention: 21 (72%) Control: 18 (67%)	Sleep (Insomnia Severity Index)	None
Maher, 2020, Australia	Pre-post, 12 w	n=31 adults aged 45 to 75	56.2 (8.0)	n=21 (68%)	Physical activity (Active Australia Survey) Dietary behaviour (14-item Australian Mediterranean diet adherence tool, adapted from the Prevención con Dieta Mediterránea)	None
Phillip, 2022, France	Non-RT, 17 d	n=842 adults aged 18+	Sleep Diary: 47.0 (13.6) Kanopee: 51.2 (13.4)	Sleep Diary: n=339 (69.3%) KANOPEE: 343 (64.1%)	Sleep (Insomnia Severity Index)	None
To, 2021, Australia	Pre-post, 6 w	n=151 physically inactive adults	Mean (SD) = 49.1 (9.3)	n=95 (81.9%) female	Physical activity, including steps (Fitbit flex, Active Australia survey)	None
Watson 2012, USA	RCT, 12 w	n=70 adults with BMI 25-35 kg/m^2	Intervention: 44.1 (SD NR) Control: 40.6 (SD NR)	Intervention: 28 (80%) Control: 31 (89%)	Physical activity (steps, ActiPed)	None
Werner-Seidler, 2019, Australia	Pre-post, 6 w	n=50 children aged 12–16 years with sleep difficulties.	13.71 (1.35)	n=33 (66%)	Sleep (Insomnia Severity Index, Pittsburgh Sleep Quality Index, 10-item Sleep Diary)	None
Wright, 2013, USA	RCT, 12 w	n=50 parent-child dyads (child 9-12 years, BMI >95th percentile)	Children (overall): 10.3 (1.1) Parents (overall): 40.0 (9.1)	Children (overall): n=21 (42%) Parents (overall): n=48 (96%)	Dietary behaviour (Block Dietary Data Systems Kids Food Screener version 2)	None

Supplementary Table 4. Intervention and chatbot characteristics.

Author, year, country	Intervention overview	Intervention duration and frequency and length	Chatbot only or multiple components intervention 2	Target behaviour/s	Chatbot name, delivery method, and/or delivery platform	Output	Theoretical framework	Behaviour change techniques (as reported in the paper)	Individualised
Bickmore, 2013, USA	Embodied Conversational Agent (ECA) to motivate participants to increase walking.	Daily conversations with the ECA for 2 months	Multicomponent (chatbot and pedometer)	Physical activity	Embodied Conversational Agent, software, tablet	Voice, images (animated computer characters with voice, hand gesture, gaze cues, and other nonverbal behaviour)	No	Review goals, positive reinforcement, identifying and problem-solving barriers, goal setting,	Yes
Bickmore 2013B, USA	Animated conversational agent to promote physical activity and fruit and vegetable consumption	Daily	Multicomponent (chatbot and pedometer)	Physical activity Healthy eating	Animated conversational agent, computer	Text	No	Goal setting, develop and review goals, problem solving and identify and overcome barriers, increase knowledge of health behaviour	No
Carfora, 2019, Italy	Chatbot-based intervention to reduce red meat consumption.	Daily for 2 weeks	Chatbot only	Healthy eating (red meat consumption)	Facebook Messenger, smartphone	Text	No	Negative consequences on health	No
Carlin, 2021, United Kingdom	Intelligent personal assistant for promoting and maintaining physical activity and health behaviours	Daily and weekly tasks, prompts, and reminders for family members.	Chatbot only	Physical activity, healthy eating	Amazon Alexa, Amazon Echo Dot Smart speaker	Voice	No	None	Yes
Cushing, 2021, USA	Computer program that adapts text messages based on user input to promote adolescent physical activity.	Multiple daily messages/ reminders	Chatbot only	Physical activity, sedentary behaviour	NUDGE, server-side computer program that adapts text messages, smartphone	Text	No	Goal setting and review, self-monitoring, feedback on goal attainment and revise future goals.	Yes
De-Jongh González, 2022,	App aimed to promote healthy lifestyle behaviours by targeting dietary, physical	NR	Chatbot only (as part of the app)	Physical activity, diet, screen time, sleep"	Aim2Be app (Ayogo Health Inc), Aimbot app, computer or smart phone	Text	Social cognitive theory, Player Experience and Need Satisfaction	Self-regulatory strategies, goal setting, self-monitoring, and graded tasks to facilitate behaviour change by strengthening self-regulatory skills, enjoyment,	Yes

	activity, screen time, and sleep.				with internet access		Model, the Agency, Challenge, Uncertainty, Discovery, and Outcomes framework	engagement, motivation, peer support, behaviour modeling, interaction, social support	
Dhinagaran, 2021, Singapore	A conversational agent promoting healthy lifestyle behaviour changes in the general population	Messages were sent to the participants four times a week (once for each of the 4 topics of focus) for 4 weeks	Chatbot only	Physical activity, healthy eating, sleep	Chatfuel (Precilla), a Facebook Messenger smartphone	Text	Capability, Opportunity, Motivation, Behavior model	None	Yes
Friederichs, 2014, Netherlands	Web-based, motivational interviewing intervention with an avatar, to increase physical activity	NR	Chatbot only	Physical activity	Computer	Avatar, text	No	Motivational interviewing	No
Gardiner, 2017, USA	Embodied Conversational Agent (ECA) to teach lifestyle modifications to urban women.	Daily for 30 days	Chatbot only	Physical activity, healthy eating, mindfulness, stress management)	Gabby embodied conversational agent; web-based, computer	Text, images, speech	No	Goal setting, problem solving, education	Yes
Hassoon, 2021, USA	AI-based health coaching agent (MyCoach) delivered through a smart speaker or AI-based autonomous progressive smart coaching delivered through text messaging (SmartText)	Daily	Multi-component (smart speaker or SMS chatbot, Fitbit Charge HR2)	Physical activity	MyCoach (Amazon Echo/ Alexa smart speaker); MyText, (smartphone)	Voice or text	NR	NR	Yes
King 2007, USA	Telephone-assisted physical activity counselling by an automated telephone-linked computer system	15x 10-15 min contacts during the study	Multi-component (telephone-linked computer system, physical activity mailouts, pedometer)	Physical activity	CHAT "Community Health Advice by Telephone", conversational agent, telephone-	Voice	Social Cognitive Theory and the Transtheoretical Model	Physical activity assessment, progress evaluation, problem-solving, goal setting, feedback, positive support and tailored advice, self-monitoring.	Yes

					linked computer system				
Kramer, 2020, Switzerland	Chatbot-guided interventions to encourage users to reach personalized daily step goals.	Every day, the Ally app sets a personalized activity goal based on each participant's past activity data.	Smartphone app (with chatbot included)	Physical activity	Ally, smartphone app,	Text	Health Action Process Approach and self-determination theory	Incentives, Planning, Self-monitoring prompts, Goal setting	Yes
Lorenz 2019, Germany	Online intervention with automated feedback for treatment of insomnia.	6 sessions of CBT-I with an animated sleep coach	Chatbot only	Sleep	Mementor Somnium, internet-based (computer)	Speech, visual (graphs)	CBT-I	Goal setting, intention formation, barrier identification, problem solving, feedback, review of goals, information on consequences, action planning, instruction, prompts/ cues	Yes
Maher, 2020, Australia	PA and diet intervention (MedLiPal) delivered via artificially intelligent virtual health coach.	11 weekly check-ins and 24/7 chatbot	Multi-component (Paola, Garmin wearable activity monitor, MedLiPal website, diet and activity log)	Physical activity Healthy eating	Paola, iOS or Android smartphone or tablet; Messaging app (Slack)	Text	None	Goal setting, Problem-solving, Goal review, Self-monitoring with feedback, Social support, Reattribution, Use of credible sources	Yes
Phillip, 2022, France	Smartphone-Based Virtual Companion to Treat Insomniac Complaints	Daily	Chatbot only	Sleep	Louise, Kanopee smartphone app,	Text, graphs/ figures, images	No	Feedback	Yes
To, 2021, Australia	Machine learning–based physical activity chatbot that sent out daily motivational messages in relation to goal achievement, and automatically adjusted the daily goals	Daily updates on the physical activity level for self-monitoring, sent out daily motivational messages	Multi-component (Chatbot + Fitbit)	Physical activity	Ida, The Facebook Messenger app, Smartphone	Text	COM-B model	Capability (adaptive feedback on goal achievement), Opportunity (educational content), and motivation, goal setting, self-monitoring.	Yes
Watson 2012, USA	Virtual coach (automated and follows an algorithm-driven script) to increase physical activity	3+ times a week for 5-10 minutes each session.	Multi-component (Chatbot, pedometer, ActiHealth website)	Physical activity	Virtual coach, (conversation agent), software installed on home computer	Speech, text, images	Behavioural and social cognitive theory	Goal setting, shaping, self-monitoring, positive reinforcement, problem solving, education, and social support.	Yes

Werner-Seidler, 2019, Australia	CBT-based Sleep ninja app (with integrated chatbot) for insomnia	6x 5-10min training sessions and nightly prompts	Chatbot only	Sleep	Sleep ninja app, smartphone running iOS or Android	Text and visual images	No	Stimulus control	Yes
Wright, 2013, USA	Automated interactive voice response system, to deliver a healthy weight management and sedentary behaviour intervention.	Twice weekly for 12 weeks	Chatbot only	Healthy eating, physical activity, sedentary behaviour (TV time)	Automated interactive voice response (IVR) systems, telephone	Voice	Social Cognitive Theory	Goal setting, contracting, parent-child meetings, problem-solving, self-monitoring, instructions on how to perform the behaviour	Yes

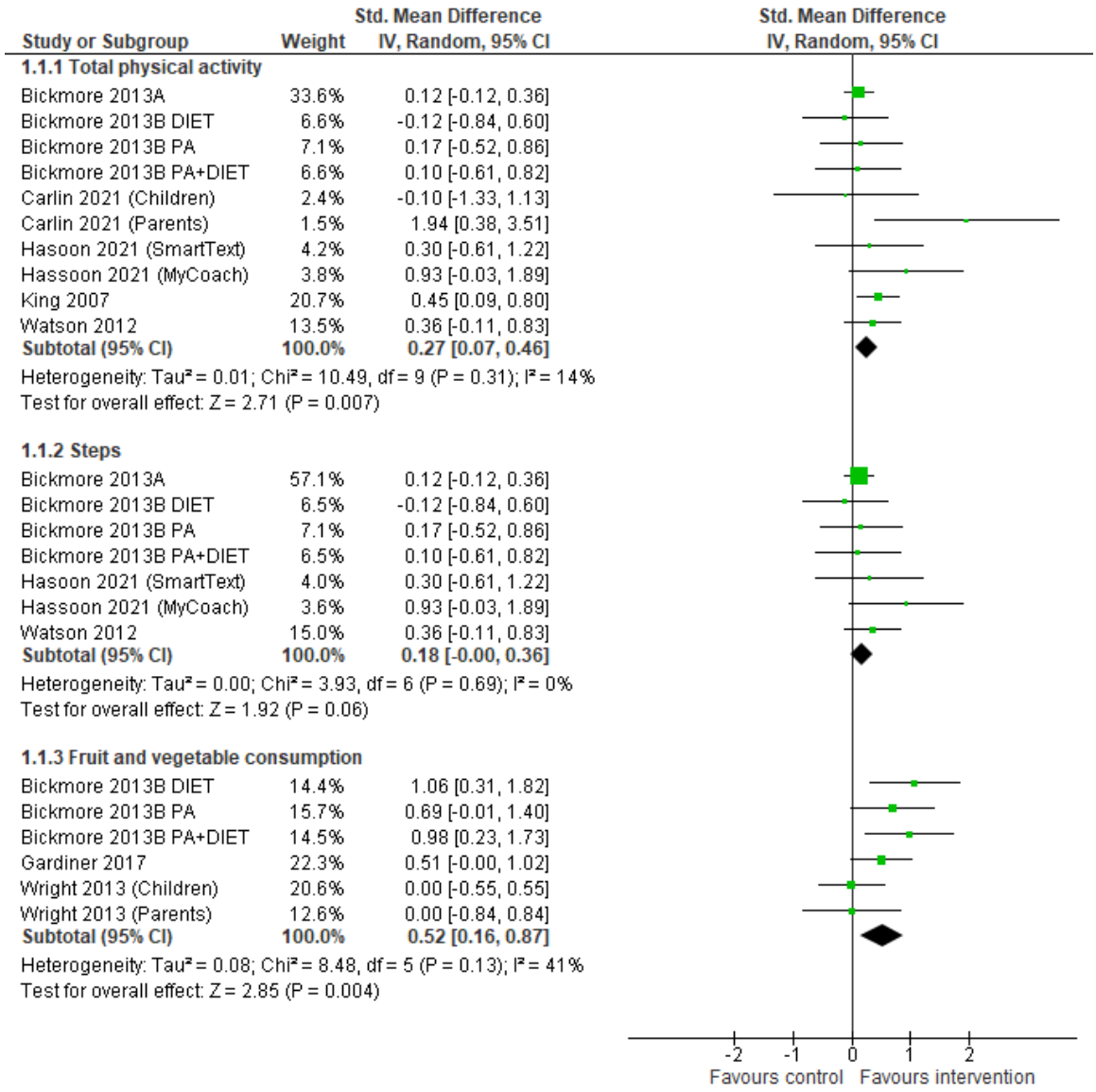
Supplementary Table 5. Subgroup analyses (using data from randomised controlled trials and single-group pre-post studies) for total physical activity, steps and fruit and vegetable consumption.

	Number of studies	Number of participants	I^2 (%)	Standardised mean difference (95% CI)	P-value
Total physical activity					
Intervention duration					0.83[1]
≤6 weeks	4	882	21	0.29 (0.13, 0.46)	<0.01
>6 weeks	6	661	15	0.27 (0.08, 0.45)	<0.01
Intervention type					0.81[1]
Chatbot only	5	934	49	0.27 (0.03, 0.51)	0.03
Multicomponent intervention	5	493	0	0.31 (0.14, 0.47)	<0.01
Output					0.88[1]
Speech/voice	4	477	45	0.32 (0.02, 0.63)	0.04
Text	6	1126	0	0.30 (0.18, 0.42)	<0.01
Assessment method					
Self-report	3	305	0	0.29 (-0.02, 0.61)	0.07
Objective measure	7	1298	10	0.28 (0.15, 0.41)	<0.01
Use of AI/NLP					0.57[1]
Yes	6	600	16	0.24 (0.04, 0.44)	0.02
No	4	1003	16	0.31 (0.17, 0.46)	<0.01
Steps					
Intervention duration					0.08[1]
≤6 weeks	3	706	0	0.36 (0.22, 0.49)	<0.01
>6 weeks	3	454	0	0.14 (-0.05, 0.33)	0.14
Intervention type					0.66[1]
Chatbot only	3	862	34	0.30 (0.09, 0.51)	<0.01
Multicomponent intervention	3	308	0	0.23 (0.04, 0.43)	0.02
Output					0.23[1]
Speech/voice	2	332	0	0.17 (-0.05, 0.39)	0.12
Text	4	944	0	0.32 (0.19, 0.46)	<0.01
Use of AI/NLP					0.79[1]
Yes	3	396	0	0.25 (0.04, 0.45)	0.02
No	3	880	33	0.28 (0.10, 0.46)	<0.01
Fruit and vegetable consumption					
Intervention duration					0.17
≤6 weeks	2	83	63	0.16 (-0.63, 0.96)	0.68
>6 weeks	3	186	9	0.77 (0.45, 1.09)	<0.01
Intervention type					0.79
Chatbot only	1	61	NA	0.51 (0.00, 1.02)	0.05
Multicomponent intervention	3	228	50	0.59 (0.25, 0.93)	<0.01
Output					0.02[1]
Speech/voice	2	105	34	0.16 (-0.34, 0.66)	0.53
Text	2	184	0	0.90 (0.57, 1.23)	<0.01
Use of AI/NLP					0.02[1]
Yes	2	184	0	0.90 (0.57, 1.23)	<0.01
No	2	105	34	0.16 (-0.34, 0.66)	0.53
Sleep duration					
Intervention type					0.04[1]
Chatbot only	1	56	NA	0.48 (-0.05, 1.01)	0.08

Multicomponent intervention	2	1168	97	1.45 (-0.61, 3.51)	0.17
Sleep quality					
Intervention type					0.02[1]
Chatbot only	2	116	86	0.41 (-0.48, 1.30)	0.37
Multicomponent intervention	2	1168	95	0.96 (-0.43, 2.35)	0.17

[1] P-value represents overall test for subgroup differences (Hedges g).

AI: artificial intelligence; NLP: natural language processing.



Supplementary Figure 1. Meta-analyses of effects of chatbot intervention versus control conditions (using data from randomised controlled trials only) for overall physical activity, steps, and fruit and vegetable consumption (there was insufficient data for all other outcomes to conduct meta-analyses) using Hedge's g.