Review

Conversational Agents and Avatars for Cardiometabolic Risk Factors and Lifestyle-Related Behaviors: Scoping Review

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Abstract

Background: In recent years, there has been a rise in the use of conversational agents for lifestyle medicine, in particular for weight-related behaviors and cardiometabolic risk factors. Little is known about the effectiveness and acceptability of and engagement with conversational and virtual agents as well as the applicability of these agents for metabolic syndrome risk factors such as an unhealthy dietary intake, physical inactivity, diabetes, and hypertension.

Objective: This review aimed to get a greater understanding of the virtual agents that have been developed for cardiometabolic risk factors and to review their effectiveness.

Methods: A systematic review of PubMed and MEDLINE was conducted to review conversational agents for cardiometabolic risk factors, including chatbots and embodied avatars.

Results: A total of 50 studies were identified. Overall, chatbots and avatars appear to have the potential to improve weight-related behaviors such as dietary intake and physical activity. There were limited studies on hypertension and diabetes. Patients seemed interested in using chatbots and avatars for modifying cardiometabolic risk factors, and adherence was acceptable across the studies, except for studies of virtual agents for diabetes. However, there is a need for randomized controlled trials to confirm this finding. As there were only a few clinical trials, more research is needed to confirm whether conversational coaches may assist with cardiovascular disease and diabetes, and physical activity.

Conclusions: Conversational coaches may regulate cardiometabolic risk factors; however, quality trials are needed to expand the evidence base. A future chatbot could be tailored to metabolic syndrome specifically, targeting all the areas covered in the literature, which would be novel.

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KEYWORDS

chatbots; avatars; conversational coach; diet; physical activity; cardiovascular disease; hypertension; cardiometabolic; behavior change; hypertension diabetes; metabolic syndrome; mobile phone

Introduction

Background

Metabolic syndrome (MetS) is a highly prevalent condition that affects up to approximately 30% of adults aged >65 years worldwide [1]. It consists of multiple symptoms, namely abdominal obesity, glucose intolerance, hypertension, and high cholesterol as well as low high-density lipoprotein [2]. It is associated with a substantially increased risk of premature morbidity and mortality from diabetes and cardiovascular disease (CVD) [2]. Low levels of physical activity (PA) are strongly associated with MetS, including obesity and overweight [3], high blood pressure [4], and insulin intolerance [5]. Furthermore, low levels of activity are significantly associated with increased risk of complications of MetS, including diabetes and CVD [5,6]. In addition, research has found that losing weight by approximately 5% to 10% results in significantly reduced MetS-associated markers [1] in patients with existing disease, highlighting that MetS may be modifiable through lifestyle-related weight interventions. Dietary modifications, including reduced sodium, sugar, and fat intake, are also highly beneficial for reducing the risk of the syndrome and its complications [7].

In recent years, mobile health (mHealth) has increasingly been used to support behavior changes related to weight loss, including improving dietary intake and physical activity [8]. Research on the use of mHealth interventions has found support for a moderate effect size for assisting with weight loss [8]. This includes the use of SMS text messaging for behavior change and mHealth apps that target weight loss using a range of behavior change techniques (BCTs) [9], including self-monitoring, feedback, goal setting, education, tips, personal tailoring, reminders, encouragement, and social and professional support [8]. mHealth is a form of health care that enables timely accessibility, portability, and personalized medicine tailored to the needs of the user [10,11]. It includes smartphones, PDAs, MP3 players, iPads (Apple Inc), smart clothing, and smart watches [10,11].

Emerging research in the mHealth field has focused on developing conversational agents that can simulate human professional interactions for managing different health problems [12], including weight issues [13]. Furthermore, avatars have also been developed to display a conversational coach in addition to written conversational text, simulating real-life interactions with a professional, such as a live fitness coach [14,15]. Having a conversational coach complement or replace metabolic-related health advice from professionals may increase accessibility and enable more timely health monitoring and diagnosis of health conditions [15] such as MetS if physicians also gain access to patient data. Given that technology in the field is advancing, it is time to determine whether these conversational agents are effective for assisting with MetS-associated risk factors, including overweight, obesity, physical inactivity, and unhealthy dietary intake. There is also a need to better understand what types of weight-related and MetS-related studies have been undertaken using conversational agents and to identify challenges with the technology and future areas of research.

Aims

This review aimed to better understand the evidence surrounding the use of conversational coaches for metabolic-related risk factors and biomarkers. Furthermore, this review aimed to determine whether conversational coaches are effective for improving weight-related behaviors and metabolic indicators and whether conversational agents are acceptable for consumers as agents of behavior change.

Research Questions

- Research question (RQ) 1: How effective are conversational agents (chatbots and avatars) for weight-related behaviors, including diet and exercise?
- RQ 2: How effective are conversational agents for improving metabolic risk factors, including blood pressure, cholesterol, abdominal obesity, and glucose (diabetes management)?
- RQ 3: What are consumers' perspectives on the use of chatbots?

Methods

A systematic review of PubMed and MEDLINE was conducted in December 2021 for all relevant studies on conversational coaches for metabolic risk factors published over the last 10 years. Google Scholar was also searched for any additional papers along with manual hand searching.

Inclusion and Exclusion Criteria

This review included studies on chatbots or avatar conservational agents that acted as coaches for improving metabolic health behaviors, including dietary intake (sodium and sugar intake), PA, and weight (including abdominal obesity). Studies that evaluated one or more physiological indicators of metabolic health or risk factors for MetS, such as diabetes, glucose intolerance, hypertension, cholesterol, and serum triglycerides, were also included. Studies must have been published in the English language to be included. Chatbots that were used for survey reasons but not primarily for targeting weight-related or metabolic risk factors were excluded. Studies whose primary focus was not on conversational coaches were excluded (including those that had an avatar element but did not primarily focus on evaluating it). Studies on wearables that did not include avatars or chatbots were excluded. Studies in pregnant women were excluded.

Search

The keywords included word variations for “chatbot,” “virtual assistant,” “virtual coach,” or “avatar”; weight-related behaviors, including “diet,” “exercise,” or “weight”; and metabolic risk factors, including “hypertension,” “cholesterol,” or “diabetes.” The search strategy is shown in Textbox 1.

Textbox 1. PubMed search strategy example.

1. Cardiometabolic risk factors

- Weight

"obesity"[MeSH Terms] OR "obese"[tiab] OR "obesity"[tiab] OR "overweight"[tiab] OR "overweight"[tiab] OR "BMI"[tiab] OR "Body mass index"[tiab] OR "Body mass index"[MeSH Terms] OR "physical activity"[Tiab] OR adiposity [tiab] OR weight gain[tiab] OR body weight[tiab] OR "abdominal visceral fat"[Tiab] OR "adipose tissue"[MeSH Terms] "weight loss"[Mesh] OR "weight loss"[tiab] or "metabolic syndrome"

- Diet and physical activity

diets[tiab] OR "diet"[mesh] OR diet[tiab] OR "energy intake"[tiab] OR nutrition[tiab] OR "diet, food, and nutrition"[MeSH Terms] OR diets[tiab] OR Caloric restriction[tiab]OR "physical activity"[tiab]

- Hypertension

hypertension[tiab] OR "Blood Pressure"[tiab] OR Prehypertension[tiab] OR BP[tiab] OR "Systolic blood pressure"[tiab] OR SBP[tiab] OR "Diastolic blood pressure"[tiab] OR DBP[tiab] OR cardiovascular[tiab] OR hypotensive[tiab] OR "Hypertension"[MeSH] OR "Blood Pressure"[MeSH] OR "Prehypertension"[MeSH]

- Cholesterol

"cholesterol"[MeSH Terms] OR cholesterol[tiab]

- Diabetes

"Diabetes Mellitus"[MeSH] or diabetes[tiab] or diabetic[tiab] or prediabetes[tiab] or pre-diabetes[tiab] OR "glucose"[MeSH Terms] OR "glucose"[tiab]

AND

2. Technology

chatbot*[tiab] OR chat bot[tiab] OR chat-bot[tiab] OR chatter bot[tiab] OR chat bots[tiab] OR chat-bots[tiab] OR chatter bots[tiab] OR chatterbot*[tiab] OR smart bot[tiab] OR smartbot[tiab] OR smart bots[tiab] OR smartbots[tiab] OR smart-bot*[tiab] OR virtual agent*[tiab] OR virtual character*[tiab] OR virtual coach*[tiab] OR virtual human[tiab] OR avatar*[tiab] OR embodied agent*[tiab] OR relational agent*[tiab] OR animated character*[tiab])

1 AND 2

Screening and Data Extraction

Titles were screened for relevance to the RQs, followed by abstract and full-text retrieval of eligible studies that met the inclusion criteria. A second reviewer (LL) screened the abstracts and full texts against the inclusion and exclusion criteria to ensure agreement. Quantitative and qualitative data were extracted and summarized in a tabular format, including study characteristics, measures, outcomes, and intervention details.

Results

General Description

LL and ME screened the final selected papers individually. A total of 52 full texts were selected [13,14,16-65]; however, after double peer screening, 1 protocol and 1 dated technology were removed. The final number included 50 papers [13,14,16-59,61-63,66]. Details of the search process and reasons for exclusion are illustrated in Figure 1 [67].

Most of the studies were feasibility and usability studies. A few studies were qualitative and explored consumer perspectives on conversational agents for weight-related behaviors [14,19]. The countries where the studies were conducted included Australia, the United States, Italy, Spain, and Taiwan [13,14,16-29]. Most of the studies explored virtual agents for diet and exercise, with only 2 (4%) exploring chatbots for hypertension management [17,19]. The majority were conducted among adults, but 3 (6%) were conducted among teenagers and preteens [14,26,29]. The study characteristics and results are summarized in Table 1.

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart of the search and screening process. MetS: metabolic syndrome.

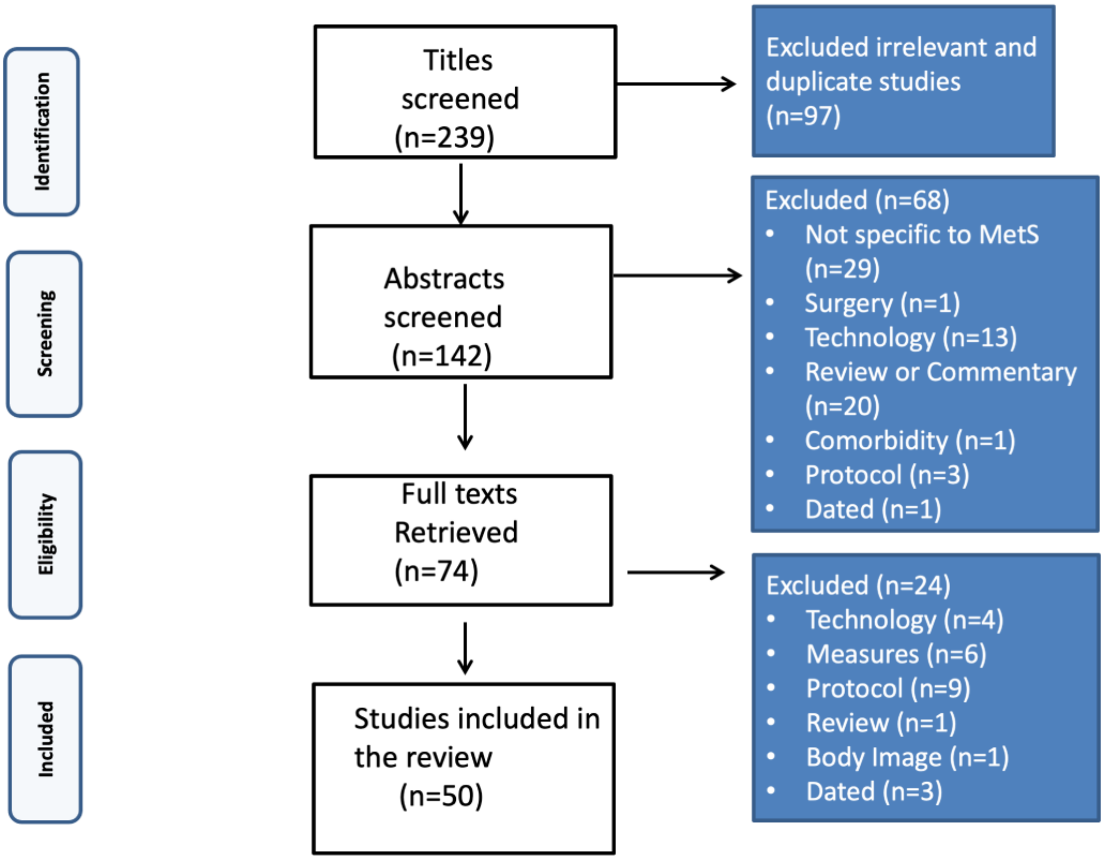

Table 1. Study characteristics.

Study and year	Location, N, and design	Sex (%)	Age (years)	Health targets and measures	Technology and procedures	Outcomes
Echeazarra et al [17], 2021	• Location: Spain • N=112 • Design: 2-year RCT[a]	Female: 42	Mean 52.1	BP[b]	• Tensiobot (telegram app) • Reminders to check BP • Education on how to properly check BP using videos • Warnings and graphic feedback on BP • GPs[c] can connect with the app to access patient data • Advice offered 24/7	• No significant differences in adherence between groups • Bot group had higher levels of knowledge on good practice skills for BP (t=2.11; *df*=82.3; 95% CI 0.39-12.6; *P*<.05) • Measurements (*P*<.05) • Bot found to be acceptable/likable • Adherence after intervention: 85%
Griffin et al [19], 2021	• Location: United States • N=15 • Design: mixed methods questionnaires with semistructured interviews qualitative	Female: 53	Mean 59 (SD 11)	BP	• Theoretical discussion around chatbots for hypertension medication management	• Most patients were interested in and open to trying a chatbot for hypertension medication management and reminders • Privacy concerns and usability with mobile phones
Larbi et al [20], 2021	• Location: Switzerland • N=30 • Design: feasibility study	Female: 50	Range 18-69	PA[d]	• MYA social media chatbot	• Perceptions of usefulness and informativeness: 53% • User friendly: 83% • Failed to understand user input: 63.3% • Potential confusion with using the technology 43.3%
Lin et al [27], 2021	• Location: Taiwan • N=96 • Design: factorial experimental study with 4 arms	Female: 53	Mean 21.5; range 18-42	PA (core muscle exercise)	• VR[e] avatar	• Increase in PA (vector movement) of 986.7 (SD 1.03) points in in normal realistic avatar relative to muscular avatar • Higher self-efficacy for core muscle exercise in normal avatars vs muscular avatars in female participants (+0.66, SD 0.1 points) and higher levels than in male participants (+0.9, SD 0.2 points) • *P*<.05
Dol et al [37], 2021	• Location: The Netherlands • N=71 • Design: qualitative study	Female: 100	Mean 44.4 (SD 12.86); range 19-70	Emotional eating	• Conversational coach for emotional eating	• The design of the conversational coach should integrated dialectal behavioral coaching strategies, as preferred by participants with emotional eating behavior

Study and year	Location, N, and design	Sex (%)	Age (years)	Health targets and measures	Technology and procedures	Outcomes
Lin et al [27], 2021	• Location: Taiwan • N=104 • Design: experimental design study	Female: 50	Mean 70.39 (SD 6.51); range 60-88	PA perceived exertion Self-efficacy	• Assigned to either age-matched or young avatars for PA Theory: Proteus effect of avatar embodiment • Watched videos in a digital gym where they exercised • Wore a head-mounted display	• Older male participants assigned to young avatars had higher perceived exertion than counterparts assigned to older ones (+1.56, SD 0.31 points; male participants only) • Female participants assigned to young avatars had higher self-efficacy for future exercise than counterparts (+0.45 points) and male participants • *P*<.05
Maher et al [13], 2021	• Location: Australia • N=31 • Design: proof-of-concept study	Female: 67	Range 45-75	PA, Mediterranean diet, and weight	• AI[f] Paola chatbot teaches users about exercise and uses BCTs[g], including goal setting, self-monitoring, and feedback	• Mean increase in diet score: 5.7 (95% CI 4.2-7.3) • Mean PA increase: 109.8 min (95% CI 1.9-217.9; *P*<.01) • Mean weight loss: 1.3 kg (95% CI −2.5 to −0.7; *P*<.05) • *P*<.01 • No significant changes in blood pressure
Hickman et al [40], 2021	• Location: United States • N=109 • Design: 2-arm RCT	Female: 59	Mean 52 (SD 11)	Hypertension, quality of the physician-patient interaction	• Avatar intervention or video on hypertension management	• Scores for the quality of the patient-provider interaction were better over time (F_3=5.25; *P*<.01) in the within-subjects analysis along with a time by experimental condition interaction (F_3=2.91; *P*<.05) • Between-subject effects per treatment were insignificant • No significant changes in blood pressure
Napolitano et al [49], 2021	• Location: United States • N=136 • Design: feasibility study (12 weeks)	Female: 100	Mean 27.8 (SD 5.4)	Weight, diet, and PA; exercise self-efficacy	• Conversational coach gave lessons on health behaviors	• No significant results were found for differences in weight, PA, or consumption of fast food between the intervention arm and control groups • High attrition 44% • Goal achievement for nutrition <10%
Santini et al [55], 2021	• Location: Austria, Italy, and Netherlands • N=60 (2 waves) • Design: qualitative study with focus groups and phone interviews	Female: 53.3% wave 1; 51.6% wave 2	Mean 61.9	Health behaviors, diet, and PA	• Embodied coach for diet and PA	• Desire for the avatar to motivate older adults to exercise • Supportive tone and language that is not authoritarian or patronizing
Krishnakumar et al [44], 2021	• Location: India • N=102 • Design: pre-post intervention (1 arm) • 16 weeks	Female: 31.4	Mean 50.8	Diabetes (blood sugar), diet, PA, and weight (logged)	• Wellthy CARE mobile app	

Study and year	Location, N, and design	Sex (%)	Age (years)	Health targets and measures	Technology and procedures	Outcomes
						• The use of the Wellthy CARE digital therapeutic for patients with T2D[h] showed a significant reduction in the mean levels of HbA_{1c}[i] −1.16% (95% CI −1.40 to −0.92; *P*<.01); FBG[j] (−11 mg/dL), and PPBG[k] (−22 mg/dL); *P*<.05 • Weight decreased by 1.32 kg (95% CI −0.63 to −2.01 kg) after 16 weeks
Dhinagaran et al [36], 2021	• Location: Singapore • N=60 • Design: one arm web-based feasibility stud	Female: 62	Mean 33.7	Diet, PA, sleep, and stress	• Chatbot for diabetes prevention, diet, exercise delivered over Facebook Messenger (Meta Platforms Inc)	• Engagement: 50% • Retention: 93% • Satisfaction: high at 92% • 50% agreed that the chatbot was acceptable and usable • No significant changes in health behaviors including PA • Minimal improvement in diet: increase in fruit intake (3 portions) by 4% and vegetables once per day by 2%
To et al [61], 2021	• Location: Australia • N=116 • Design: quasi-experimental study (6 weeks)	Female: 81.9	Mean 49.1 (SD 9.3)	PA	• Fitbit plus a chatbot in the Messenger app	• Usability score: 89.4% • Desire to continue using: 35.4% • Helped them: 53% • Mean PA increase: 154.2 min/week (95% CI 2.28-5.63) • OR for meeting PA guidelines: 6.37 (95% CI 3.31 to 12.27) • Mean steps/day increase: 627 (95% CI 219 to 1035)
Mitchell et al [48], 2021	• Location: United States • N=158 • Design: mixed methods survey with qualitative interviews study	Female: 100	Mean 56 (SD 11) intervention; 57 (SD 11) control	Diabetes	• Avatar for diabetes self-management	• Avatars provide support for diabetes self-management via 3 areas (self, social, and physical) that are linked with engagement
Strombotne et al [58], 2021	• Location: United States • N=590 • Design: quasi-experimental study	Female: 11	Mean treatment=58.1; control=57.7	Diabetes and risk factors	• Conversational coach and ketogenic diet	• BP decrease (systolic): 1.4 mm Hg (95% CI −2.72 to 0.14) • Diastolic BP levels decreased: −1.43 (95% CI −2.72 to −0.14) mm Hg • HbA_{1c} decreased: −0.69 (95% CI −1.02 to 0.36) • Diabetes medication fills: −0.38 (95% CI −0.49 to −0.26) • BMI: −1.07 (95% CI −1.95 to −0.19) kg/m^2
Alves Da Cruz [31], 2020		Female 48.1	Mean 63.4 (SD 12.7)	HR[l], BP, and RR[m]		

Study and year	Location, N, and design	Sex (%)	Age (years)	Health targets and measures	Technology and procedures	Outcomes
	• Location: Brazil • N=27 • Design: cluster randomized crossover trial				• Avatars with exergames for PA in patients undergoing cardiovascular rehabilitation	• Increase in HR (z=82.8; *P*<.01) and RR (z=12.9; *P*<.01) during and (5 min) after exergame • Changes in systolic BP but not diastolic with differences within moments z=11.26 (*P*<.01) • With no statistical significance between groups
Kowalska et al [43], 2020	• Location: Poland • N=249 • Design: cross-sectional study	Female: 36.5	Mean 65.3 (SD 13.8)	CVD[n]	• Telehealth voice technology with health professionals and voice conversational agent	• High desirability for telehealth consultations with a cardiologist combined with a conversational agent • Desirability for telemonitoring of vitals: 67.5% • 70.7% wanted a consultation with a cardiologist remotely
Piao et al [51], 2020	• Location: South Korea • N=106 • Design: Exploratory Randomized Controlled Trial • 12 weeks	Female: 56 intervention; 57 control	Range 20-59	Health behaviors (diet and exercise); SRHI[o]	• Lifestyle coaching chatbot • Informed by habit formation • Cues and goals	• Significant improvement in health behavior • The intervention group had higher scores on the SRHI of 7.12 (SD 5.57) with *P*<.05 at 4 weeks; no significant differences between groups at 12 weeks, PA remained higher after 12 weeks (*P*<.05)
Naylor et al [50], 2020	• Location: United States • N=20 • Design: pilot study	N/A[p]	Mean 8.4 (SD 1.3)	VO_2 (mL × kg^{-1} × min^{-1}) using indirect calorimetry questionnaire on liking and motivation	• Children played tennis with their friend and an avatar	• Increased VO2 during game play in both cooperative (3.8 + 1.8 mL × kg^{-1} × min^{-1}) and competitive play (4.4 +1.8 mL × kg^{-1} × min^{-1}) compared with resting condition (*P*<.01) • Children liked exercising more in cooperative games than in competitive games (*P*<.01) • No differences between game styles in motivation for PA (*P*>.05)
Hahn et al [39], 2020	• Location: United States • N=42 (child and parent dyads [n=40 completed baseline and follow-up measures]) • Design: pilot intervention	Female (children): 55.2	Treatment: mean 8.06 (SD 1.10); control: mean 7.5 (SD 1.38)	PA using Fitbit and self-report on motivation for PA	Children wore Fitbit with a personalized dog avatar for socializing and support (digital fitness kiosk); theory informed (social cognitive theory)	• Completion rate: 81.63% • Mean number of PA goals reached: 3.28 • Mean time playing with pets: 20.35 min • Mean number of active min: 66 min (no statistical significance was found)
Navarro et al [24], 2020	• Location: United States • N=305 • Design: 3-arm RCT	Female: N/A	Mean 20.0 (SD 2.2); range 18-37	Cardiac frequency, step counts, accelerometer, and HR monitor	• Randomly assigned to avatars embodying them (same face) or different from them (strangers) • Avatars wore normal clothes or gym clothes	

Study and year	Location, N, and design	Sex (%)	Age (years)	Health targets and measures	Technology and procedures	Outcomes
						• Higher cardiac output (frequency) from 6 to 12 min in users of avatars that had a similar appearance (face) • Higher output in users with avatars that additionally wore sports clothing at 6-7 and 10-minute periods • Support for the Proteus effect hypothesis • No changes in step count
Davis et al [16], 2020	• Location: Australia • N=28 • Design: pilot single-arm study	Female: 68	Mean 56.2 (SD 8); range 45-75	Diet: Mediterranean diet adherence tool. Weekly log for diet and step count; activity tracked using a wrist worn tracker (Garmin) that syncs with Paola. Minutes of moderate to vigorous PA assessed with Active Australia Survey	• Conversational assistant Paola for diet and PA consisted of educational modules, weekly check-ins, and 24/7 availability for PA and diet questions • 12-week pilot	• Assisted with increasing PA (step goal achieved 59% of the time) • Adherence to diet: 91%
Navarro et al [23], 2020	• Location: Spain • N=42 • Design: 3 arms—2 avatars vs control	Female: 100	Mean 31.9 (SD 11.7); range 19-61	PA, IPAQ[q], self-efficacy to regulate exercise, and PA enjoyment scale (PACES[r])	• Avatar: ideal (perfect body) or normal (matching the participant) and web-based intervention without the avatar	• Increased PA in all groups ($F_{1,39}$=15.8; P<.01; web-based intervention effects) • No effects of time by avatar assignment, ie, interaction
Balsa et al [32], 2020	• Location: Portugal • N=20 • Design: usability study with qualitative interviews	Female: experts 88.9%; end users 27.3%	Mean 62.62; mean end users 70.9; mean experts 54.3	Usability of the app for diabetes medication adherence and improving lifestyle behaviors, diet, and PA	• The conversational coach resembles a human • Integrated BCTs: goal setting, self-monitoring, feedback, and social support/counseling	• Usability score: 73.75 (SD 13.31) (indicates high usability of the coach)
Chin et al [35], 2020	• Location: United States • N=15 • Design: feasibility study	Female: 60%	Mean 67 (SD 5.84)	PA	• Health coach for PA • As part of a PA program using a Google Home device (Google LLC)	• Usability was high • 80% of the participants did not experience challenges when interacting with the conversational coach
Fadhil et al [18], 2019	• Location: Italy • N=19 • Design: validation study (4 weeks)	Female: 42	Mean 28.5; range 19-53	Diet and PA questionnaires via chatbot and motivation (HAPA[s])	• CoachAI text based conversational agent • Tailored coaching for habits	• Participants were satisfied with the agent • High trust to share personal information to the coach
Ahn et al [30], 2019	• Location: United States • N=67 • Design: field study (3 days)	Female: 61.19	Mean 11.24 (SD 0.85); range 9-13	PA and basic psychological needs	• Use of a digital dog, with and without a points-based reward system	• Higher levels of PA in the rewards points group briefly versus control ($F_{1,58}$=5.32; P<.05) • No significant effects on PA over time
Stephens et al [26], 2019	• Location: United States • N=23 • Design: feasibility study	Female: 57	Mean 15.2; range 9.7-18.5	Weight management; pre-diabetes		• Usefulness rate: 96% • Progress toward goals frequency: 81%

Study and year	Location, N, and design	Sex (%)	Age (years)	Health targets and measures	Technology and procedures	Outcomes
					• Tess text-based chatbot counsellor for healthy behavior change usability assessed with progress toward goals and engagement	
Srivastana et al [57], 2019	• Location: United States • N=10 • Design: usability study	Female: 70	Range 44-67	Prediabetes	• The web-based module used to support diabetes prevention education and a mobile app that is an electronic diary and a coach	• Success of modules 60% as they meet weight loss of 5% • Compliance with dietary recommendations: 59%-87% • Compliance with PA: 52%-93%
Thompson et al [59], 2019	• Location: United States • N=27 • Design: pilot feasibility study	Female: 73 (teens)	Range 10-15	Diabetes	• Conversational agent with human features • Conversations around diabetes education	• Attrition: low (<10%) • High satisfaction: >80% • Technical issues<10% • Teens and families had a positive experience
Thompson et al [29], 2018	• Location: United States • N=48 • Design: laboratory-based study	Female: 50	Range 12-14	PA	• PA exergame with an avatar coach	• Completion: 87.5%; teens enjoyed the game (mean enjoyment score 68%) • Vigorous PA during 74.9% of the game
Duncan-Carnesciali et al [38], 2018	• Location: United States • N=198 • Design: cross-sectional, survey-based design using quantitative and qualitative paradigms	Female: 97.5	Range 26-76	Diabetes	• Avatar for diabetes management	• Ethnicity including Arab or Middle Eastern, Asian, and White or European descents as well as age were significantly associated with an excellent rating of the video with *P*<.05
Klaassen et al [42], 2018	• Location: N/A • N=21 • Design: usability study	Female: 52	Mean 13.9	Diabetes	• Conversational coach game with feedback • Integrates BCTs including information on consequences	• Usability index of 44.18 (SD 21.18; low)
Sinoo et al [56], 2018	• Location: Netherlands • N=21 • Design: experimental study	Female: 37	Mean 9.2 (SD 1.1)	Diabetes self-management	• Avatar for gameplay and diabetes self-management vs robot	• Preference for the robot (mean friendship score 4.0, SD 0.6) over the avatar (mean friendship score 2.9, SD 0.7) as a companion • Usability moderate: 58.7 (SD 24.5) • Similarity of avatar to robot led to greater friendship (*P*<.01)
Tongpeth et al [62], 2018	• Location: Australia • N=22 (development of the application) • N=10 (feasibility testing) • Design: pilot feasibility	Female: 10	Mean 52.2 (SD 10.4)	Cardiovascular: acute coronary syndrome management	• An interactive, avatar-based education application for improving patients' knowledge of, and response to, acute coronary syndrome symptoms	• Symptom recognition increased: 24% • Satisfaction: 87.3% • Knowledge increase: 15.7%

Study and year	Location, N, and design	Sex (%)	Age (years)	Health targets and measures	Technology and procedures	Outcomes
Friedrichs et al [63], 2014	• Location: Netherlands • N=958 • Design: 3-arm RCT	Female: 60.4	Mean 42.9 (SD 14.5)	PA; Dutch Short questionnaire	• Avatar with a web intervention or a digital web-based text condition versus control	• Significant increases in PA in the intervention arms versus control with B=0.39 in the avatar arm and B=0.44 in the text arms (*P*<.05) • No differences between the text arm or the avatar arm for PA
Stein et al [25], 2017	• Location: United States • N=70 • Design: longitudinal observational study	Female: 74.5	Mean 47 (SD 1.8); range 18-76	Weight and dietary intake	• Lark Weight Loss Health Coach (participants were a part of a diabetes prevention weight loss program) • Advice on dietary intake and PA • BCTs used include motivation, encouragement, reminders, and education	• 31% increase in healthy eating • Mean weight change: −2.4 kg (SE 0.82; 95% CI −4.03 to −0.77)
Thompson [66], 2016	• Location: United States • N=48 (round 1) • N=43 (round 2) • Design: mixed methods survey with qualitative interviews	Female: 50	Range 12-14	Preferences for a PA intervention	• Exergame with a self-representation avatar	• Desired gameplay with the avatar that could be controlled by eliciting the desired action: 62.5% male and 58.3% female • Personalized avatar: 41.7% • Most common avatar features to be customized: • Body: 95.8% • Clothing: 93.8% • Hair color: 87.5%
Behm-Morawitz et al [33], 2016	• Location: United States • N=90, female=100% (the 2 male participants were excluded) • Design: qualitative research and RCT	Female: 100	Range 18-61	Weight and PA self-efficacy	• Avatar (embodied) and video game to promote PA	• Findings support the use of the avatar for weight management t_{18}=2.15 (*P*<.05) with the intervention losing 1.75 lbs versus 0.91 lbs in the control • No effects on dietary self-efficacy • Strong correlation with avatar sense of self-presence and confidence in meeting health goals (r=0.95; *P*<.01) • Themes: avatar benefits include motivation and assisting with self-efficacy for PA • Barrier: games are not for everyone
Kuo et al [45], 2016	• Location: Taiwan • N=76 • Design: 2-arm intervention in laboratory	Female: 63.15	Mean 21.2	Eating behavior observed in laboratory	• Avatar that embodied the participants or was a weight-reduced (thinner) version of them	• Avatars that embodied a thinner version of the participants shaped eating behaviors more compared with identical self-avatars; including selecting less ice cream (Cohen d=0.35; F1,73=7.8; *P*<.01) and opted for sugar free drinks (Cohen d=0.29; F1,73=6.0; *P*<.01)

Study and year	Location, N, and design	Sex (%)	Age (years)	Health targets and measures	Technology and procedures	Outcomes
Ruiz et al [54], 2016	• Location: United States • N=41 • Design: laboratory study	Female: 0	Mean 64 (SD 7)	Cardiovascular behavioral risk factors (diet and exercise)	• Avatar vs a voice (nonanimated) for behavior change linked with CVD	• Avatar increased intentions (+1.56 points) to improve lifestyle behaviors relative to controls (Cohen d=0.77 *P*<.01; t_{36}=2.48) • Differences in confidence to change risk of heart disease was nonsignificant
LeRouge et al [14], 2015	• Location: United States • N=41 • Design: user-centered design, 3 phases with focus group and interviews	N/A	Teenagers: 12-17	Perceptions of the avatar for diet and exercise	• Interactive avatar coach	• Desire for a fun human-like interaction • Desire for a lifestyle coach and personal embodiment avatar and an authoritarian one • Desire for customization of the avatar • Advice on activity on the go and meals when eating at home • Goal setting • Technical issues could be a barrier including the internet
Thomas et al [28], 2015	• Location: United States • N=37 • Design: feasibility and usability study with pre-post test	Female: 100	Mean 55.0 (SD 8.2)	Weight-related eating behaviors	• Conversational coach for weight (focuses on dietary intake and managing eating behaviors)	• The coach assisted with perceptions of increased self-control over eating (confidence to control eating: +1 point (SD 0.2; *P*<.01) and skills for controlling eating +0.7 points (SD 0.1; *P*<.01)
Ruiz et al [53], 2014	• Location: United States • N=150 • Design: RCT	Male: 100	Mean 62 (SD 7.9)	Diabetes (knowledge)	• Computer program with an avatar to increase diabetes knowledge and medication (adherence)	• There were no significant differences between the intervention group and control group in terms of knowledge, with *P*=.95 • Satisfaction levels were higher in the digital intervention group (F4=3.11; *P*<.01)
Li et al [46], 2014	• Location: Singapore • N=140 • Design: factorial design experiment	Female: 41	Range 9-12	PA attitudes, motivation, and game performance	• Assigned to varying avatars (normal and overweight)	• Healthy weight avatars linked with greater scores in motivation for Nintendo exercise (F1,134=5.49; *P*<.05 [boys]) attitude, and performance (F1,134=2.27; *P*<.05 [girls])
Napolitano et al [22], 2013	• Location: United States • N=128 (phase I) N=8 (phase 2) • Design: mixed methods (pilot usability testing) study with interviews	Female: 100	Mean 34.1 (SD 13.0); range 18-60 (phase 1)	Weight, PA [14], and weight self-efficacy; satisfaction; preferences survey and interviews	• Avatar for diet and exercise • Informed by social cognitive theory • Behavioral modeling • Targeted self-efficacy • 4 weeks	• The avatar helpful: 87.5% • Mean weight loss after 4 weeks: 1.6 (SD 1.7) kg • All women found that it helped with their diet and exercise • Most were interested in the avatar
Bickmore et al [34], 2013	• Location: United States • N=122 • Design: 4-arm RCT (2 months)	Female: 61	Mean 33.0 (SD 12.6); range 21-69	Diet (NIH[t]/NCI[u] fruit and vegetable scan) and PA (IPAQ)	• Animated counselor • for diet and PA (separate and combined)	

Study and year	Location, N, and design	Sex (%)	Age (years)	Health targets and measures	Technology and procedures	Outcomes
						• No significant differences between groups in PA after adjustment • Fruit and vegetable servings significantly increased in the diet arm (F3,103=4.52; *P*<.01) • No significant differences in weight or PA between groups • Likability: Karen was perceived as nice by 35% of the participants • 50% of the participants found Karen helpful
Johnoson-Glenberg et al [41], 2013	• Location: United States • N=19 • Design: pilot feasibility study (pre-post study)	N/A	Grades 4-12 (ages 9-18)	Diet (nutrition and food choice test and knowledge)	• Diet and exercise game (exergame) with an alien interactive coach	• Differences in dietary knowledge of nutrition pre and post intervention (t=4.13; *P*<.01) and knowledge of the My Plate content in the study (t=3.29; *P*<.01)
Ruiz et al [52], 2012	• Location: United States • N=30 • Design: comparative pilot with three arms (with randomization) intervention	N/A	N/A	PA	• 3D avatar-based VR intervention	• Participants completing a 3D VR intervention mediated by avatars resembling the participants showed significant improvement in PA (*P*<.05) • No significant effects of the intervention on obese or overweight participants
Mestre et al [47], 2011	• Location: France • N=6 • Design: laboratory experimental study	N/A	Range 19-25	PA enjoyment	• Digital coach paced participants in a VR bicycling setting	• The VR coach and VR cycling were associated with higher levels of PA enjoyment (F2,10=13.24; *P*<.001) in the feedback group

[a]RCT: randomized controlled trial.
[b]BP: blood pressure.
[c]GP: general practitioner.
[d]PA: physical activity.
[e]VR: virtual reality.
[f]AI: artificial intelligence.
[g]BCT: behavior change technique.
[h]T2D: type 2 diabetes.
[i]HbA_{1c}: hemoglobin A_{1c}.
[j]FBG: fasting blood glucose.
[k]PPBG: postprandial blood glucose.
[l]HR: heart rate.
[m]RR: respiratory rate.
[n]CVD: cardiovascular disease.
[o]SRHI: Self-Report Habit Index.
[p]N/A: not applicable.
[q]IPAQ: International Physical Activity Questionnaire.
[r]PACES: physical activity enjoyment scale.
[s]HAPA: Health Action Process Approach.
[t]NIH: National Institutes of Health.
[u]NCI: National Cancer Institute.

Weight

A few studies evaluated the effects of conversational assistants for weight loss [13,22-24,44]. The study by Maher et al [13] in Australia found that the conversational assistant (chatbot) Paola assisted with a weight loss of 1.3 kg at 12 weeks follow-up (95% CI –0.1 to –2.5). In addition, there was a mean waist circumference reduction of 2.5 cm at follow-up compared with baseline (95% CI –3.5 to –0.7). The chatbot used a range of BCTs, including goal setting, self-monitoring, education, social support, and feedback to users on PA and the Mediterranean diet [13]. A study in the United States found that the Lark Weight Loss Coach, an artificial intelligence–powered bot, assisted participants with a weight loss of 2.38% (95% CI –3.75 to 1.0) with a mean use of 15 weeks [25]. The conversational agent was informed by cognitive behavioral therapy and used a range of BCTs, including education, encouragement, and reminders surrounding dietary and PA targets [25]. The determinants of weight loss included the duration of using the artificial intelligence program and engaging with it, logging meals, and the number of counseling sessions completed [25]. A large study in the United States examining the use of an avatar coach that targeted self-efficacy and modelled vicarious experiences for diet and PA (4 weeks) found that women lost an average of 1.6 (SD 1.7) kg at follow-up [22]. A study in India found that an avatar coaching app with calls from health professionals assisted with a weight loss of 1.39 kg (95% CI –0.63 to –2.01; $P<.01$) at 16 weeks [44]. A randomized controlled trial (RCT) with a qualitative component found that avatars increase motivation and PA self-efficacy linked with weight loss [33]. However, some studies did not report any significant weight loss [34,49].

Diet

A few studies evaluated the effects of conversational coaches (chatbots and avatars) on dietary intake and found that overall, the coaches assisted with ameliorating dietary habits and goals [13,16,25,28,34,45,49]. A study in the United States found that healthy dietary intake improved in 30% of participants who were using a conversational weight loss coach [25]. Another study found that eating behaviors improved in users of a conversational eating coach, which included increases in the mean scores for the perceptions of skills to eat healthily and self-control over their eating habits (0.7 increase in points) as well as confidence to control food consumption in social situations (1.0 increase in points; $P<.01$) [28]. The Paola chatbot study found a mean increase in the Mediterranean diet score [68] of 5.8 points at 12 weeks follow-up [13]. Similarly, a study of Karen, an animated counselor, found significant increases ($F_{3,103}=4.5$; $P<.01$) in fruit and vegetable intake in the diet intervention arm relative to the control group [34]. A further study found that eating behaviors were shaped by the appearance of the avatar, with healthier eating behavioral patterns in participants who had thinner avatars including reduced portions of ice cream and opting for healthier sugar-free drink alternatives [45].

Physical Activity

A few conversational assistant PA coaches, including chatbots and avatars, were evaluated, and overall, they assisted with increasing PA [13,16,21,23,24,27,55,63]. Most of them involved exergames with the avatar. However, one of the studies did not find any improvements in PA among the 2 avatars, attributing improvements only to the web-based part of the intervention [23], and another study did not find a difference between the web-based intervention and the chatbot (only when considering a standard control) [63]. A preliminary usability study in Australia found that step count goals increased 59% of the time in users of the chatbot that targeted PA and that participants had a preference for personalization and greater knowledge-based content [16]. Another pilot study of Paola, the chatbot in Australia, found that it assisted with increasing mean step count by 109 minutes per week at 12 weeks follow-up (95% CI 1.9-217.7) [13]. A study involving an exergame that used a PA avatar coach in teens found that 75% of the time, participants engaged in 15.88 (SD 5.8) minutes of vigorous PA throughout the game [29]. Participants also wanted the avatar to have a supportive and nonpatronizing or nondisparaging tone in interactions regarding PA and found that it could motivate older adults when adequately personalized [55]. Similarly, a study in children also found that they desired the option to personalize the avatar, including controlling and customizing its physical appearance during game play when exercising [66].

Proteus Effect

The Proteus effect is a phenomenon wherein individuals embody and emulate the behaviors of their virtual characters such as avatars [69,70]. A few studies demonstrated support for the Proteus effect when it came to PA behaviors, although the type of avatar varied. A study in Taiwan found that younger looking avatars were associated with higher levels of PA than older looking avatars but only in women. Male participants had higher levels of PA than female participants who used an older looking avatar, highlighting differences between sexes [27]. A further study found a higher cardiac output resulting from increased intensity of PA in adult users of an avatar that resembled them and wore gym clothes when compared with avatars that appeared unfamiliar like strangers in regular clothing, which reduced heart rate [24]. Similarly, a study in Taiwan found increases in physical activity assessed in movements (986.7 points higher) in users of a "normal avatar", more closely resembling them than the most muscular avatar [21]. They also found that self-efficacy was higher (0.66 points) for core muscle exercises in female participants assigned to normal avatars relative to their muscular counterparts and male participants assigned to the same standard avatar (0.9 points higher), with $P<.05$ [21]. Similarly, dietary behavior was also shaped by thinner embodied avatars in another study [45].

Diabetes

Most diabetes studies were feasibility studies. The results of diabetes conversational coaches were mixed. A few studies did not have positive findings concerning the applications with avatars for diabetes [42,53]. However, one study reported a usability score of 73, which is relatively high. Notably, the study integrated a range of BCTs, including goal setting, feedback, self-monitoring, social support, and counseling [32]. Low usability scores were reported in a few studies, including one that reported an overall score of 44.58 (SD 21.18) [42].

Similarly, an RCT of a diabetes coaching avatar did not find that knowledge increased relative to controls, but intervention participants in the computer-based programmed dynamic avatar had higher satisfaction levels (F_4=3.11; P=.01) [53]. Another study in the United States in participants with prediabetes found that 60% of patients had successfully completed the modules and met weight targets during 6 months of use (60% success rate) [57]. Engagement was also moderately high (50%) in a study in Singapore involving a chatbot, although usability was high along with retention (93%) [36]. In a study in teenagers, attrition was also low, and 80% of the participants were satisfied with the conversational diabetes coach [59]. A study that evaluated a coaching application for diabetes found an improvement of –11 mg/dL in fasting blood glucose levels [44]. However, the intervention also involved phone calls from health professionals [44]. Similarly, an avatar application with a ketogenic diet program assisted with a reduction in hemoglobin A_{1c} levels of 0.69% (SE 0.168%) [58]. Qualitative research found that avatars created an environment of social presence that facilitated social support and coherence for patients with diabetes [48]. In another study of avatars combined with robots, children preferred robots over avatars, but their friendship increased if the two had a greater similarity, which impacted usability [56].

CVD and Associated Risk Factors

A few studies evaluated the use of conversational coaches for CVD. One of them was a pilot study of the Tensiobot chatbot [17], a coaching application that teaches users how to properly check their blood pressure using recommended practice guidelines and provides users with graphic feedback and reminders. The study found that the chatbot group did not differ from the control group in terms of adhering to blood pressure measurement recommendations. However, there were significantly higher levels of knowledge (+6.53 points) with regard to checking blood pressure in the chatbot group than in the control group (P<.05) [17]. Blood pressure (diastolic) was significantly reduced, that is, by 1.43 mm Hg (SE 0.65; 95% CI –2.72 to –0.14; P<.01), in users of an avatar application that also involved a ketogenic diet [58]. In addition, a mixed methods study with a qualitative component found that users in general were interested in trying a hypertension chatbot for medication management as well as for health communication and self-care [19]. In addition to these studies, a general diet and PA chatbot study evaluated changes in blood pressure, but these changes were nonsignificant [13]. A study in Poland found high desirability for a CVD voice technology coach, in addition to accessing phone-based telemedical services by health professionals [43]. A further study in Brazil evaluated avatars for cardiovascular rehabilitation and found that an avatar with an exergame influenced heart rate, systolic blood pressure, and respiratory rate during the intervention and up to 5 minutes after its completion [31]. Furthermore, a study found that the avatar intervention increased the intent to improve lifestyle behavioral risk factors in patients relative to controls (P=.01), although confidence did not change [54]. Finally, a study evaluated a cardiovascular educational avatar application and found that it increased symptom recognition by 24% and knowledge of CVD by 15%, with a high satisfaction rate of 87% among patients [62].

User Perceptions

Several studies found that users were interested in using conversational coaches for lifestyle behaviors [14,19,22]. Overall, participants enjoyed using the chatbots and avatars or found them helpful for diet, exercise, and hypertension management [17,22,25,26,29]. User-friendliness was reported by 83% of the participants in a study that evaluated a PA social media chatbot [20]. Similarly, 87.5% of women in a weight loss avatar intervention found it helpful [22]. With the exception of studies on diabetes conversational coaches, adherence or completion of tasks was high across studies on lifestyle (diet and PA) conversational coaches, ranging from 85% to 90% [13,16,17,29]. The qualitative study themes were related to the desirability for a conversational coach for hypertension and weight-related behaviors, especially for one that simulates human interaction closely, provides advice and goals for meals when cooking, and provides educational support [14] including for hypertension management [14,19].

Technological Challenges

A few tech challenges were brought up across the studies. Although users found that the conversational coach answered basic questions correctly, failure to understand and respond to more complex or spontaneous questions was reported in the studies. The percentage of failure for spontaneous or complex questions was 79% in one study [16], and participants in another study gave a high ranking for the chatbot’s failure to recognize their input [20]. Paola chatbot correctly answered spontaneous questions on diet in 4 out of 20 attempts, with a success of 20%, while the percentage of correctly answered simple and predetermined questions and responses was 96% and 97% [16].

Discussion

Principal Findings

This review aimed to better understand the effectiveness of virtual coaches for managing metabolic health and weight-related risk factors. It appears that virtual coaches hold potential for assisting patients with improving their dietary intake and PA behaviors, leading to subsequent weight loss. However, more studies that are larger and sufficiently powered RCTs are needed to establish a stronger evidence base. RCTs are the gold standard of evidence but are often costly and time-consuming [71,72]. Most of the studies were limited, as they were pilot studies. Ideally, it would be of interest to research long-term weight changes and cardiometabolic risk factor modifications over longer periods.

It appears that PA interventions may benefit from using avatars that embody the participant. The Proteus effect is based on the hypothesis that users adjust their behavior by modeling the virtual character with which they interact [73]. Thus, it seems that incorporating an avatar may enhance mHealth chatbot interventions, as it adds the element of user interaction and promotes the modeling of behavior through embodiment [73]. However, 1 (2%) study did not find that the avatars enhanced the effects of the web-based intervention [23].

We also found that consumers seemed to be interested in and enthusiastic about trying virtual coaches for managing their weight-related behaviors and blood pressure. Adherence to the intervention was also high throughout the studies, which indicates that this technology is acceptable and usable for patients. However, there is a need to undertake qualitative research on developing a MetS coach to further understand consumer perspectives. The main barrier to consider when developing future virtual agents is that the virtual agents did not always answer correctly to spontaneous responses. As consumers want personalized and tailored mHealth for weight-related behaviors [74], future applications should ensure that the virtual agents are sufficiently advanced to be able to interact with users in a natural and personalized manner.

It appears that diabetes virtual coaches should be improved to maximize engagement and adherence, as not all studies found that they were helpful. Although outside the scope of this review, we note that some studies used BCTs, which could suggest that future applications may benefit from integrating BCTs [13,20,22,25,32,42,51]. In addition, we identified some studies on blood pressure and CVD management, which demonstrated preliminary improvement in patients with hypertension as well as knowledge of CVD. However, we did not identify any virtual coaches for managing MetS. Therefore, there is a need to develop virtual coaches specifically tailored to this syndrome and its associated risk factors. Such virtual coaches could be integrated into a combined synchronized application that involves diabetes and CVD education and monitoring.

MetS is linked with high blood pressure, which is one of the main hallmarks of the disease. The theoretical mechanisms underpinning the development of hypertension in patients with MetS have included a combination of endothelial dysfunction, systemic inflammation, adiposity, and oxidative stress [75]. Dysfunction in the renin-angiotensin system has also been theorized to be a determinant [75]. Obesity itself has also been identified as a risk factor for high blood pressure in MetS [76]. Blood pressure is modifiable to some extent through lifestyle changes previously described, including dietary sodium restriction, PA, stress reduction [77], and medication [78]. Future virtual coaches may target hypertension as part of a MetS intervention, and this review found that patients are willing to try chatbots for managing their blood pressure.

MetS is also associated with high glucose levels of at least 100 mg/dL when patients are fasting [78], which indicates that they are in the prediabetes stage, as diabetes begins at fasting glucose levels of 126 mg/dL [79]. In a recent longitudinal study, patients who reduced their fasting blood glucose levels decreased their overall risk of diabetes by 54% when compared with their counterparts who did not improve their blood sugar levels (95% CIs exclude 1) [80]. A recent study found that individuals who consumed high amounts of sugar were 32% more likely to have MetS than their counterparts [81]. Thus, a future MetS virtual coach could target blood glucose monitoring and offer personalized advice on optimum sugar intake.

In addition to targeting dietary intake, PA is integral to managing this syndrome. A meta-analysis found that the risk of cardiovascular events was reduced by 30% in physically active individuals compared with those who were inactive [6]. A longitudinal study in middle-aged women found that increasing step counts significantly reduced, by 30%, the risk of MetS in this population and that they had clinically improved levels of the protective cholesterol high-density lipoprotein, whereas their serum triglycerides had significantly decreased [82]. A review found that walking on a daily basis reduced the risk of type 2 diabetes by nearly half [5]. Furthermore, recent research suggests that sedentary behavior, including sitting time, is an independent and significant risk factor for MetS syndrome [83]. Thus, PA chatbots and avatars, which were found to increase PA time, steps, and self-efficacy in this review, could be integrated into a comprehensive future MetS interventions.

Given that chatbots and avatars hold potential for increasing PA and reducing sedentary behavior, as well as improving dietary intake, studies are needed to evaluate their effectiveness for managing the symptoms and risk factors associated with MetS specifically.

In addition, stress is often an underlying determinant of maladaptive weight-related behaviors, including binge eating, emotional eating, and an unhealthy dietary intake as well as weight gain [84-88]. Future avatar and chatbot interventions for cardiometabolic factors could also consider integrating psychological supportive interventions such as mindfulness-based stress reduction, which assists with weight and stress [89-93], as an element.

Conclusions

In summary, we found that virtual coaches hold promise for regulating diet, PA, weight, and possibly hypertension. However, studies on virtual coaches are few in number; therefore, more research, including RCTs, is needed to confirm the effectiveness of virtual coaches. Overall, most participants in the reviewed studies were interested in using virtual coaches, including chatbots and avatars, for regulating their weight-related behaviors, and study adherence was good. Future interventions could be ameliorated to reduce technical challenges associated with these conversational agents and ensure that they respond correctly to complex and spontaneous questions. Furthermore, future research could involve developing a comprehensive conversational agent for MetS, such as a health coach that simultaneously targets diet (sodium, sugar, and fat intake), exercise, weight (including abdominal obesity), blood pressure, and diabetes, and evaluating it. This would include a health coach that simultaneously targets diet (sodium, sugar, and fat intake), exercise, weight (including abdominal obesity), blood pressure, and diabetes.

Conflicts of Interest

None declared.

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Abbreviations

BCT: behavior change technique
CVD: cardiovascular disease
MetS: metabolic syndrome
mHealth: mobile health
PA: physical activity
RCT: randomized controlled trial
RQ: research question

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