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# Novel App- and Web-Supported Diabetes Prevention Program to Promote Weight Reduction, Physical Activity, and a Healthier Lifestyle: Observation of the Clinical Application

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## Abstract

**Background:** The increasing incidence of type 2 diabetes mellitus presents as a tsunami of health problems and health care costs. Preventing this development needs to target the underlying rise in metabolic syndrome cases through obesity and unhealthy lifestyle. Obesity is frequently perceived as a social issue with implicit psychological strain; health apps/weight-reduction programs are mushrooming from this side. The present program intends to bring weight reduction into the hands of HCPs by utilizing advanced digital technology.

**Methods:** The prospective observational study analyzed 166 patients with metabolic syndrome as treated for weight reduction in 23 medical practices in Germany. Two approaches were observed: usual care (UC; n = 57) and a personalized health management program (PHM; n = 109). Key for PHM was the interaction between HCP and patient: reinforcing lifestyle changes through personalized goals and HCP-feedback via app- and web-based communication. Comparing PHM/UC was based on a time-to-success (5% weight reduction) analysis by Cox regression. Further exploratory analyses addressed the comparison of achievers and nonachievers.

**Results:** Cox regression adjusted for sex, age, and BMI revealed a chance ratio for weight reduction of 6.2 (2.4-16.2, $p$ = .0003) favoring PHM. Expected success rates were 44.8% for PHM, 11.5% for UC. PHM achievers reduced their weight by 8.0% and lowered their BMI by 2.7 points. Motivation for lifestyle changes represented a key for success.

**Conclusions:** The approach of enhanced interaction of HCPs and patients via app- and web-based communication was a clear success and delivered favorable responder rates. Treating obesity from a medical viewpoint will help to deepen the motivation for changing lifestyles. The study represents a cornerstone for a wider scoped application of these novel digital health approaches.

## Keywords

metabolic syndrome, T2DM prevention, weight reduction, web-app-portal

The increasing incidence of type 2 diabetes mellitus (T2DM) in the world of Western lifestyle presents as a major health problem implying elevated cardiovascular risks. The rise of T2DM is not stopping or slowing up, on the contrary, it is still accelerating, despite of some existing prevention programs. Recently Horner et al[1] reported 29.1 million US manifest T2DM patients along with 86 million prediabetes patients, including substantial portions of young adults.[2] These figures illustrate the drastic extent of this epidemic representing a tsunami of coming health problems with ensuing health care costs; largely parallel developments apply to Europe/Germany. This calls for novel approaches especially in the wake of a new more digitalized care process.

Obesity and unhealthy lifestyle may represent the most important factor for developing the metabolic syndrome.[3] In Germany the prevalence of the metabolic syndrome is around 20%, with regional and gender-related differences.[4] Persons with metabolic syndrome bear a fivefold elevated risk of

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T2DM and a doubled risk to develop atherosclerosis and cardiovascular disease.[5]

Several interventional studies have shown that a change of lifestyle toward weight reduction and more physical activity was able to at least delay the onset of T2DM.[6,7] The Finnish Diabetes Prevention Study showed that regular individual consulting of the patients led to drastically reduced risk for developing T2DM with a sustained effect over seven years.[8,9] The US Diabetes Prevention Program (more than 3000 patients)[10,11] employed "case managers" to individually support the lifestyle modification. In effect, this approach led to a relevantly reduced risk of T2DM compared to control. Furthermore, randomized trials[12] in different countries as well as recent studies and meta-analyses[13-18] have corroborated the positive effects of lifestyle modification. These findings found their way into national and international guidelines for prevention of T2DM recommending weight reductions and physical activity.[12,19,20]

Why don't we see more weight reduction programs in routine medical care? The obstacles may be the targeted persons themselves: perceived as a personal stigma, obesity in many cases comes along with psychological strain and reduced self-esteem, but is not accepted as a real medical condition. So, it's no wonder that several commercial weight loss programs are conducted by private companies. Here obesity is addressed from its social aspects, but not from an evidence-based medical viewpoint. However, these programs reveal at least temporary success in many cases, and thus their contribution should be acknowledged.

From a health care perspective, it is highly desirable to implement the state of medical knowledge about T2DM prevention into routine medical care. In Germany, persons with metabolic syndrome are most likely seen in general or internal medicine practices—mostly not for obesity, but for other conditions. Therefore, these practices could and should represent an important leverage for bringing lifestyle modification as a medical intervention into force. The extent and status of current weight reduction programs initiated by these practices are largely unknown, as well as to which degree they exist at all and which methods are favored. There is little to nothing of published information about actual approaches or success rates.

The lessons learned from the T2DM prevention studies clearly point to a crucial role of individual consulting and enhanced interaction of patients and health care professionals. This underlines again that personalizing treatments is an important move to improve success rates, as it is seen in other areas of medicine.

Based on a conventional patient-practice setting it is very difficult for payers and health care professionals to implement a dense personal feedback in weight reduction programs. Medical weight reduction programs share the pitfall of most prevention initiatives as there is no indication or actual suffering requiring clinical intervention, no reimbursement and patients might not see the necessity. When looking for solutions, we should realize that it would always be necessary to call for the patient's insight and compliance. New options emerge from the advanced communication potency of smartphones, the evolving digitalization of practices, and the fact that smartphones achieved a high coverage also in the middle-aged population and in patients who need to be tested and evaluated. This will require a transformation process by all participants involved in the health care system. There are myriad available health apps, but there is a real need for more qualified programs fostering the interaction of HCPs and patients. Here the HCP will play an important role in goal setting and discussing vital parameters as well as guiding the therapy.

The present study provides one of the first attempts to utilize smartphone apps and internet interfaces for implementing a medically supervised and personalized weight reduction program. Prevention approaches that utilize mobile phone/smartphone/web features reported added success.[1,21-23] The present app- and web-supported program focused on facilitating weight reduction for adults with metabolic syndrome. A key new element was the enhanced patient-HCP interaction, by implementing agreed goals in weight reduction and in daily physical activity, and by feedback tools through individualized messages from the HCP directly to the patient's smartphone. The program was embedded in an outpatient setting also offering pertaining training sessions in the practices including courses for nutritional advice. A statutory German health insurance (Techniker Krankenkasse, TK) supported the pilot project.

The mission of this program can be summarized in three points:

- Bring weight reduction and lifestyle modification away from a personal lifestyle topic by involving qualified health care professionals with an evidence-based medical perspective.
- Capitalize on advanced digital technology to allow for close and personalized interaction of HCPs with the patients.
- Foster sustainable lifestyle changes and T2DM prevention while staying affordable for the health care system. Establish this way a win-win situation for patients and the health care system.

## Methods

### *Patients*

The study intended to observe the clinical application of two weight reduction programs in 23 practices (general, internal medicine or diabetology) in Germany: one program offered usual care (UC) for weight reduction according to the standards of the individual practices; a second novel program utilized app- and web-supported tools for personalized health management (PHM). The prospective observational study was approved by ethics committee and all data processing followed the laws of German personal data protection.

An informed consent was signed by 233 patients with metabolic syndrome (PHM 148, UC 85), age range 35-60. There were 67 without any information beyond the baseline visit (PHM 39, UC 28). This left 166 observable patients (PHM 109, UC 57). Both programs were offered for a 1-year duration.

## Data Acquisition

*Personal Health Care Management via Accu-Chek View App and Web-Based Portal.* The prevention program PHM is a cloud-based approach addressing patients with metabolic syndrome. The Accu-Chek View app was developed in collaboration of Roche Diabetes Care Germany and SAP Health. Implementing PHM in this study received support from a statutory health insurance (Techniker Krankenkasse, TK). The program was initiated in nine German states involving medical practices with substantial experience in metabolic syndrome patients (each caring for at least 60 patients with metabolic syndrome). The practices received detailed instructions about the use of web access and the possibilities to interact with the patients.

Patients of the PHM group received instructions on how to use the Accu-Chek View app, as well as a BG measuring device. The app featured a pedometer which transferred daily steps automatically to the app. Measurements of weight, abdominal girth, blood pressure, and blood glucose were to be entered by the patients themselves. At baseline, participants could complete questionnaires via smartphone about their attitude toward health, lifestyle, self-image, and eating pattern. The participants were invited to attend a free course (up to nine classes) teaching basic knowledge about adequate nutrition and physical activity. In the first few classes, the participants received assistance in setting their personal goals regarding weight reduction and physical activity. Later, the classes focused more on the exchange of experiences in using the device and in implementing daily physical activity as well as in changing the daily nutritional behavior. Thereby individual problems could be named and solutions were worked out together. At each meeting the participants received as homework to further deepen the discussed advices.

At baseline, physician and patient agreed on personal health goals regarding weight and physical activity. During the study, the app provided optical feedback to the patients regarding the status of weight/steps and goals. Via the web-based portal, the physicians had access to the patient data, and could give feedback, initiate messages to the patients or modify the goals.

*Usual Care Group.* Study data for the UC group were recorded upon inclusion into the study (baseline); follow-up measurements for weight, abdominal girth, blood glucose, and blood pressure were obtained during 3-monthly scheduled visits.

*Both Groups.* WHO body mass index (BMI) and pertaining obesity categories were calculated. In addition, age- and sex-adjusted BMI percentiles according to the population in Germany were calculated following Hemmelmann et al.[24] Diabetes-related laboratory parameters like HbA1c, cholesterol, HDL, LDL, and triglycerides were recorded only within the practices upon unnoted clinical reasons.

*Study Goals.* Primary mission of this study of personalized health management in metabolic syndrome patients was to observe whether personalized digital feedback through the HCP would enhance the success rate of weight reduction relative to usual care. Success was defined as achieving a weight reduction of 5% during the study.

*Analysis.* Since body weight represents the primary parameter in this study, time in study was defined as the period between first and last available weight measurement. PHM participants could deliver measurements at any point in time, whereas data of UC participants were obtained at the occasion of 3-monthly visits. To allow for comparisons at any defined study time, all measurements in both groups were linearly interpolated. Main stages of comparison were the study days 90, 180, 270, and 360.

The statistical analysis addressed the comparison of the nonrandomized groups PHM and UC in their performance.

*Comparison.* The groups were nonrandomized, so it is mandatory to adjust any comparison for the well-known relevant factors sex, age, BMI at baseline in suitable regression models. Large differences in the distribution of "time in study" may severely distort the comparison. This issue was addressed by two approaches: first, by employing time-to-event methods (Kaplan-Meier, Cox regression) based on "time to success" (5% of weight reduction); second, by considering the success rates for the actual study cohorts at fixed time points (after 180 or 270 study days), also adjusted for covariates via logistic regression.

The overall effects of all considered measures, that is, the difference of values at last study day minus the baseline value, were compared between the groups (Wilcoxon rank sum test) and within the groups (Wilcoxon signed rank test), adjusted comparisons were based on linear models.

*Remark of Caution.* This observational study piloted the investigation of the usefulness of a web-app supported weight reduction program. This precluded a proper powering of the study, and therefore low $p$ values should be seen as indicating where effects may be expected but cannot be interpreted in a formal confirmative sense.

# Results

The rate of PHM patients who left the program before one year elapsed were 19.3%, 32.1%, 49.5%, and 79.8%, after 3,

**Table 1.** Comparison at Baseline.

| | PHM (n = 109) | | UC (n = 57) | | *p* values | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Raw[a] | Adjusted[b] |
| Age (years) | 49.6 | 9.3 | 52.4 | 7.1 | .09 | — |
| % females | 60.6 | — | 56.1 | — | .69[c] | — |
| Height (cm) | 172.2 | 8.5 | 169.9 | 14.0 | .36 | .03 |
| Weight at start (kg) | 95.5 | 18.0 | 88.5 | 16.9 | .008 | .008 |
| BMI (kg/m$^2$) | 32.2 | 5.5 | 30.0 | 4.4 | .01 | .02 |
| BMI percentile (%) | 79.9 | 18.6 | 69.6 | 22.7 | .005 | .007 |
| Abdominal girth (cm) | 108.5 | 12.6 | 103.5 | 11.9 | .015 | .015 |

[a]Wilcoxon rank sum test. [b]Linear model adjusting for sex and age. [c]Chi-square test.

6, 9, and 12 months, respectively; for UC these figures read 0%, 5.3%, 10.5%, 59.8%. Reasons for leaving the programs were not recorded. Here, these figures should not be termed "drop-out rate," since in this study patients merely received the opportunity to stay up to one year in either program, and there was no preplanned treatment time of one year. For comparison, Hillmer et al[25] reported for a large (n = 1915) Canadian diabetes prevention study figures of 26.8%, 46.8%, and 63% drop-outs for 3, 6, and 9 months, respectively.

## Comparison of PHM and UC

Table 1 compares the two groups at baseline. There are obvious differences in start weight, abdominal girth, BMI, and BMI percentile, each with higher values for the PHM group. Adjusting for sex and age did not resolve these differences; the adjusted *p* values hint at further differences in height.

*Effect Analysis (Referring to Time in Study).* The measurements of weight and other parameters in the PHM group could occur at arbitrary times during the study, whereas measurements in the UC were taken on approximately 3-monthly practice visits. For analysis, the measurements were linearly interpolated over time, such that for each study day defined values of the measurements were available.

Kaplan-Meier estimates for time to success of the two groups and unadjusted comparison by log-rank test are displayed in Figure 1.

The Kaplan-Meier estimate shows a marked difference between the approaches (log-rank test $p < .0001$). Over one year, the estimated achiever rate of UC amounts to 11.5 % (CI [4.6, 27.0]), while for PHM the respective estimates were 44.8 % (CI = [34.1, 57.1]). Also the crude achiever rate (ignoring time in study) was significantly different: PHM 33%, UC = 8.8%, $p < .001$.

Table 2 summarizes the results for Cox proportional hazard model for "time to success" defined by 5% weight reduction. The analysis features adjustment by sex, age, and baseline BMI. The chance to achieve a weight reduction of 5% was 6.2 times better for participants in the PHM program than for UC. This holds independently of baseline BMI, sex, or age. Also, high BMI at baseline tended to help in achieving 5% weight reduction ($p = .09$, trend).

A further statistical comparison accounting for time in study was based on the success rates for the actual study cohorts at study days 90, 180, 270, and 360. Throughout, PHM provided higher success rates than UC, statistically significant for day 180 (27.0% vs 1.9%, $p = .0076$) and day 270 (20.0% vs 2.0%, $p = .022$) shown by logistic regression adjusted for sex, age, and BMI at start.

*Effect Analysis (Ignoring Time in Study).* The effect size of each variable was defined as the individual difference between last day in study and the value at baseline. For body weight, the relative end weight in percentage, end weight/start weight, was considered as well. The within and between group comparisons are compiled in Table 3.

The within effects for the PHM group show a clear signal regarding weight-related parameters ($p < .0001$). An auxiliary regression analysis, with independent variables age, sex, and BMI at start, showed no contribution of sex and age to the weight effects, but a significant influence of baseline BMI was seen for weight effect, relative weight and BMI effect (all $p \leq .0013$), that is, those with higher baseline BMI could achieve the largest effects. This pattern was not seen for abdominal girth indicating that effects in this parameter were independent from the starting conditions. The within effects in weight parameters for the UC group did not result in any significance; however, by the lower sample size there was less statistical power than for PHM.

The two rightmost columns of Table 3 show the raw and adjusted *p* values for comparing the effects between the groups. In the raw comparison, the weight-related parameters came out significant; after adjusting for age, sex, and baseline BMI the *p* values ranged above .05 but stayed around .1. The results suggest that a higher BMI led to more weight reduction; sex and age had a minor influence on the effects in weight parameters. The results of this crude analysis largely parallel those of the time-to-event analysis and thus underline again that PHM provided more success than UC in weight reduction.

It is illustrative to compare between PHM and UC the effects for achiever and nonachiever. PHM achievers on average reduced their weight by 8.0 kg, lowered their BMI by 2.7 points, and decreased the BMI percentile by more than 10%. UC achievers performed similarly (7.4 kg, 2.5 points, 16.3%), but the figures are based on five patients only. The nonachievers of both groups ranged similarly, showing stagnation or slight increase in weight parameters.

## Comparison of Achiever and Nonachiever in the PHM Group

Overweight-related starting values were somewhat more severe for achievers than for nonachievers in the PHM group: BMI 33.1 vs 31.7 ($p = .10$) and BMI percentile 85.9 % vs 77% ($p = .059$).

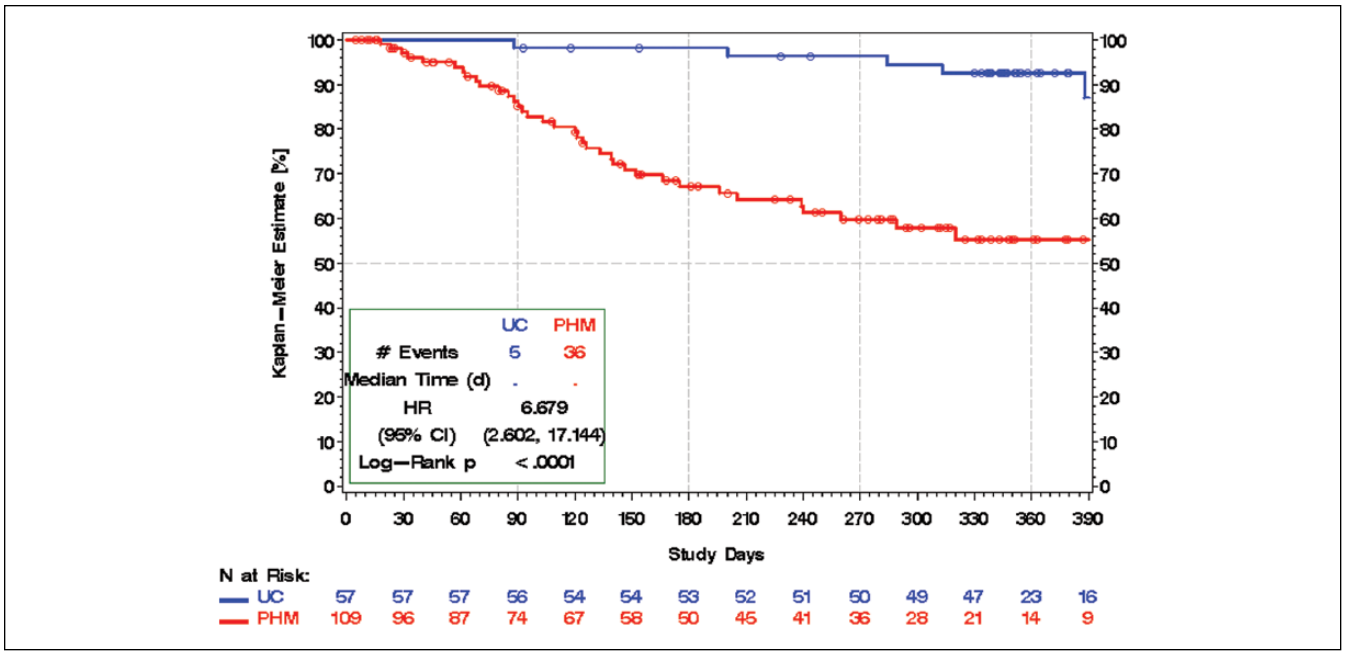


**Figure 1.** Kaplan-Meier estimate for time to weight reduction of 5% for PHM and UC.

**Table 2.** Cox Proportional Hazard Model for Time to 5% Weight Reduction.

| | Chance ratio[a] | *p* value | 95% CI[b] |
|---|---|---|---|
| PHM vs UC | 6.2 | .0003 | 2.4, 16.2 |
| Age[c] | 1.0 | .99 | 0.7, 1.4 |
| Sex | 1.3 | .50 | 0.7, 2.4 |
| BMI at start | 1.05 | .09 | 0.99, 1.1 |

[a]Usually called "hazard ratio," this describes the relative chance to achieve success. [b]Confidence interval. [c]Age measured in decades.

Table 4 summarizes study conduct variables comparing achievers (n = 36) and nonachievers (n = 73) of the PHM group. Achievers stayed on average almost two months longer in the study than nonachievers. For physical activity, nonachievers had somewhat more daily steps and had a better rate of study days in their personal step target range (nonsignificant). In one third of their study days, achievers' weight was within the personal target range, while for nonachievers this figure was 5% ($p < .0001$). Notably, nonachievers were compliant by showing favorable rates of patient measurements compared to achievers. Nonachievers received three times more active messages per study time from the practices than achievers. The frequency of clinically necessary metabolic lab measurements may serve as a rough measure of related morbidity. This figure was not different between achievers and nonachievers.

Table 5 summarizes the development for achievers and nonachievers in BG and BP. Both groups show positive effects, for achievers more pronounced and in BP clearly significant.

PHM patients had the opportunity to answer a questionnaire via smartphone about their personal attitude toward health problems, self-perception and eating pattern (19 items). Out of 109 PHM patients 58 (53.2%) answered the questionnaire. Out of the 36 achievers, 24 (67%) had responded to the initial questionnaire, while in nonachievers the rate was substantially lower 46.6% ($p = .0762$). When comparing achievers and nonachievers within this subgroup of questionnaire responders, the only sizeable difference was apparent for features measuring the strength of perceived psychological strain: participants who later became achievers had significantly higher scores in initial psychological strain from obesity ($p = .0338$).

## Discussion

The advantage of the PHM group over usual care was more pronounced than expected: PHM gave a more than 6-fold better chance to achieve a weight reduction of at least 5% compared to UC (shown by time-to-event analysis). All further analyses and covariate adjustments maintain the conclusion that PHM provided better chances for reducing weight and lowering BMI grades. In terms of success rates of participants reaching 5% weight reduction, we may expect about 45% achievers under PHM, while UC ranged around 11%. PHM achievers on average reduced their weight by 8 kg, lowered their BMI by 2.7 points, and decreased the BMI percentile by more than 10%. Weight effects in achievers and nonachievers in either group ranged similarly; this underlines that the main advancement of PHM consists of the markedly improved success rate. Since there was only a

**Table 3.** Effects Start to End Studied Within and Between Groups.

| Analysis of effects | PHM (n = 109) within effects | | | UC (n = 57) within effects | | | Between groups | |
|---|---|---|---|---|---|---|---|---|
| Variable | Mean | SD | *p* value[a] | Mean | SD | *p* value[a] | *p* value[b] | Adjusted *p* value[c] |
| Time in study (months) | 8.3 | 5.0 | | 11.6 | 2.2 | — | <.0001 | — |
| Weight (kg) | −2.4 | 6.3 | <.0001 | −0.1 | 4.0 | .99 | .0013 | .057 |
| Weight relative (%) | −2.2 | 6.8 | <.0001 | −0.0 | 5.6 | .93 | .0013 | .085 |
| BMI (kg/m$^2$) | −0.8 | 2.2 | <.0001 | 0.0 | 1.2 | .75 | .0012 | .099 |
| BMI Percentile (%) | −3.2 | 10.8 | <.0001 | −0.6 | 7.2 | .82 | .0042 | .105 |
| Abdominal girth (cm) | −2.9 | 8.0 | <.0001 | −1.0 | 5.6 | .12 | .0780 | .11 |

[a]Wilcoxon signed rank test. [b]Wilcoxon rank sum test. [c]Linear model adjusting for sex, age, BMI at start.

**Table 4.** Conduct Variables for 5% Achievers Compared to Nonachievers in the PHM Group.

| | | Achiever (n = 36) | | Nonachiever (n = 73) | | *p* values | |
|---|---|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD | Raw[a] | Adjusted[b] |
| Study conduct | Time in study (months) | 9.6 | 3.7 | 7.7 | 5.4 | .04 | .05 |
| | K-STEPS/day | 7.3 | 4.0 | 7.7 | 4.0 | .71 | .62 |
| | Days (%) with steps in targeted range | 47.4 | 28.9 | 53.2 | 28.3 | .36 | .37 |
| | Days (%) with weight in targeted range | 32.9 | 33.6 | 5.0 | 15.3 | <.0001 | <.0001 |
| Number of measurements by patients | Weight per month | 2.3 | 2.1 | 3.4 | 4.5 | .43 | .20 |
| | BP per month | 3.3 | 4.5 | 5.0 | 7.6 | .66 | .31 |
| | Abdominal girth per month | 1.1 | 1.1 | 1.4 | 1.9 | .90 | .26 |
| Number of active measures by the practices | Messages per month | 0.7 | 0.5 | 2.1 | 4.0 | .03 | .04 |
| | Lab values per month | 0.3 | 0.3 | 0.3 | 0.5 | .57 | .77 |

[a]Wilcoxon rank sum test. [b]Linear model adjusting for sex, age, BMI at start.

**Table 5.** Development of BG and BP for Achievers and Nonachievers in the PHM Group.

| | | Achiever (n = 36) | | | Nonachiever (n = 73) | | |
|---|---|---|---|---|---|---|---|
| | | Mean | SD | *p* value[a] | Mean | SD | *p* value[a] |
| Blood glucose (mg/ml) | Start | 102.2 | 14.0 | .09 | 102.2 | 15.4 | .90 |
| | End | 96.2 | 9.4 | | 101.0 | 12.9 | |
| Blood pressure systolic | Start | 139.0 | 18.9 | <.0001 | 135.5 | 17.0 | .01 |
| | End | 127.6 | 10.8 | | 128.8 | 12.3 | |
| Blood pressure diastolic | Start | 89.1 | 11.7 | <.0001 | 84.1 | 9.5 | .20 |
| | End | 80.2 | 6.8 | | 81.8 | 8.1 | |

[a]Wilcoxon signed rank test.

course on nutrition basics but no formulated diet for PHM participants, the results of this study appear even more remarkable. In view of Hamman et al,[26] a substantial reduction of the risk for manifest diabetes can be expected.

Of course, this study had its limitations—these were clearly its nonrandomized design and the lack of information about the development of nutrition and eating patterns.

So what was the real driver behind the success of PHM? There is the well-known Hawthorne or "study" effect: just the fact of being part of a study changes the patient's behavior toward the intended goal. However, this effect was present for both groups, but for PHM patients the ongoing interaction with HCPs could probably continuously reinforce this effect. Another factor may derive from the initial overweight situation at baseline: All weight parameters were worse for PHM participants; for example, the mean BMI percentile was 10% higher in PHM. Patients who feel more psychological strain from obesity were more likely to join the more ambitious PHM program. Inherent differences in motivation for change were thus likely and present an inevitable difficulty due to the

nonrandomized design. Nevertheless, it is reassuring that the advantages of PHM remained evident in all analyses with adjustment for relevant covariates.

The analyses within the PHM group to find out more about the determinants of successful weight reduction delivered at a first glance surprising results: compliance with the study rules (eg, number of measurements of weight and waist) and daily steps were rather better in nonachievers. Both groups showed a similar compliance with regard to physical activity goals and the metabolic-related morbidity did not differ. A major difference emerged for the stay in study, achievers stayed on average two months longer in the program. Achievers thus had a longer exposure to the changed lifestyle and this may partly explain their success. However, in the absence of information about changes in nutrition and eating patterns it remains difficult to understand these differences. Probably further factors contributed to success, a higher motivation for a change in lifestyle may derive for later PHM-achiever from the more severe obesity problem in terms of BMI/BMI percentile at baseline. Indeed, the prestudy questionnaire indicated that achievers perceived stronger psychological strain from their overweight compared to nonachievers. This again points to a key role of initial motivation, another call for the HCPs to enhance instructions, bringing obesity away from a social stigma to a genuine medical condition.

Apart from the gains of achievers in weight-related parameters, there were also improvements in BG, BP and blood pressure. Nonachievers did not reach the goal of 5%, but the weight-related outcomes were not worsened, smaller gains in BG and BP were found as well.

The length of stay in the study represents a possible success factor that separates achievers and nonachievers, posing the question as to why nonachievers gave up earlier. Individualized messages of the HCP were significantly more frequent in the nonachiever group, possibly due to lack of success. This is underlined by the fact that in 95% of the nonachievers' study time the weight was not within the agreed limits (67% for achievers). Reversely, this means that nonachievers received in 95% of their study time a negative feedback! At the end of the day, this may have worked as a negative reinforcement loop, inducing them to leave the program prematurely.

What are the lessons to learn from this study? The approach of enhanced interaction of HCPs and patients via web/app communication was a clear success. In a real-life setting, it led to a much higher rate of successful weight reduction than was seen in a UC program. This advocates further elaboration on this approach. Critical success factors were a pronounced motivation for changing the lifestyle and perseverance to stay in the program. For expanding the success rate, it will be helpful to enhance the instructions by the HCPs to make obese patients aware of their medical risks and to deepen this way the motivation for lifestyle changes. Patients who do not see immediate improvements can be at risk to trap into a negative reinforcement loop, ultimately resulting in leaving the program without success. To improve here, the type and frequency of interaction may be further personalized and calibrated toward the patient's wishes and needs, in line with the conclusions of Horner et al[1] and Morton et al.[27] Standardized communication should foster a positive and encouraging attitude of participants and avoid a negatively focused communication based on failure and critics. In consequence automated forms of communication must underpin positive reinforcement for the participants to actively stay in the program. The mere fact that the patient decided to participate in the program is clearly worth to signal positive reinforcement.

The study clearly showed that there are ample chances to foster relevant lifestyle changes. Noteworthy is that the employed web and app based system enables the implementation of a wider range of targets (eg, for abdominal girth, blood glucose, and blood pressure) which will allow for further interaction of HCPs with the target group. This present study represents a cornerstone for setting up a wider scoped "prevention and type-2 management program" along these lines.

## Abbreviations

BG, blood glucose; BMI, body mass index; BP, blood pressure; HCP, health care professional; PHM, personalized health management; T2DM, type 2 diabetes mellitus; UC, usual care.

## Declaration of Conflicting Interests

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