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ARTICLE

Use of digital technology to monitor dietary intake and physical activity: Issues of compliance in commercial weight-loss program users

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Abstract

Background: Health consequences resulting from excess body fat have created a need to effectively monitor weight-control behaviours. Digital technology manufactured to promote self-monitoring of weight-control behaviours is widely available, yet little is known about compliance issues associated with device use in commercial weight-loss program (CWLP) users. *Purpose:* The purpose of this study was to examine compliance issues towards using the Sensewear™ Armband (SWA™) and the CalorieSmart™ Handheld Calorie Counter (C-CS100s™). *Methods:* Participants (*n* = 15; 100% female) enrolled in CWLP were asked to use the SWA™ and C-CS100s™ for a monitoring period of 7 consecutive days. Participants were instructed to record foods at designated meal times using the C-CS100s™ plus wear the SWA™ for all non-aquatic based activities undertaken during the monitoring period. *Results:* Breakfast (*Mean* = 5.7± 1.6), lunch (*Mean* = 6.1± 1.3), and dinner (*Mean* = 6.1± 1.4) entries implied high compliance rates for use of the C-CS100s™ yet intra-individual differences in the percentage of designated meals recorded varied considerably (*Mean* = 85.4% ±18.0%, Range = 28.6% to 100.0%). Wear time for the SWA™ indicated device activation on the body between 8.3 to 23.4 hrs/day ($Mean_{Wear\ Time}$ = 19.1 ±4.9 hrs/day). Lower compliance rates for the SWA™ (*Mean* = 70.8% ±17.9%, Range = 29.6% to 85.7%) were evident compared with the C-CS100s™. *Conclusions:* Overall, the results of this study imply that compliance rates with device use recommendations for digital technology seem variable even over short epochs in CWLP users.
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Keywords: Self-monitoring, weight-control, e-health, behavioral compliance, e-tracking

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Introduction

Obesity is a known risk factor for the development of various metabolic disorders (Alberti et al., 2009) plus increased premature morbidity and mortality risk (Poirier et al., 2006). Dietary intake (Schwartz, 2016) combined with physical activity (Waleh, 2016) have been identified as key lifestyle behaviours that improve weight-control. Current population-health research indicates the prevalence of obesity in Canada has risen markedly since 1985 such that by 2019 it is predicted overweight/obese adults will outnumber normal weight adults in each province (Twells et al., 2014). These alarming trends imply greater understanding of the factors that promote weight-control behaviours is a priority for health researchers.

Self-monitoring has been linked with optimal weight-control (Burke, Wang, & Sevick, 2011). Previous studies indicate that self-monitoring is linked with short-term increases in physical activity behaviour plus reduced sedentary time (Jauho et al., 2015), improved adherence to dieticians' advice (Desroches et al., 2015), and reduced body weight and waist circumference (Burke et al., 2011). While the mechanisms detailing 'how' and 'why' self-monitoring improves weight-control remain equivocal, one approach to improving self-monitoring is use of digital technology (e.g., activity trackers, personal digital assistants, etc.). Randomized controlled trials (RCT's) using overweight/obese adults report that groups using digital technology lose more body weight across 12-weeks (Polzien, Jakicic, Tate, & Otto, 2007) and 9-months (Shuger et al., 2011) compared to groups receiving standard care. Overall, these RCT's imply that using digital technology may be a viable intervention tool for promoting optimal weight-control behaviors especially in 'at-risk' groups.

Despite the appeal of digital technology, Shaw et al. (2016) noted that compliance with device usage recommendations to promote self-monitoring is a vexing issue especially in 'at-risk' groups. Researchers have reported that device use deteriorated significantly across time, yet increased device use was positively associated with reduced body weight in overweight/obese adults participating in weight-loss RCT's (Burke et al., 2012; Polzien et al., 2007). Compliance issues may be more problematic with the use of multiple devices. For example, Shaw et al. (2016) reported low compliance rates (16.0%) in 'at-risk' individuals across a four week monitoring period with two-thirds of the sample reporting zero compliance with dietary self-monitoring and diminished use of physical activity technology evident over time. Considering the lion's share of existing studies focused on the utility of digital technology as an aid to weight-control have used only one device (e.g., Polzien et al., 2007), and/or have not reported compliance data pertaining to device usage (e.g., Shuger et al., 2011), it seems that additional studies of compliance issues in 'at-risk' groups is warranted.

Using a sample of commercial weight-loss program (CWLP) users presumed to have a vested interest in weight-control, the aim of this study was to examine compliance issues associated with using multiple devices manufactured to digitally track physical (in)activity and dietary intake. Specifically, this study addressed the following question: What are the compliance rates associated with simultaneous use of two digital technology devices manufactured to monitor weight-control behaviors? No *a priori* hypotheses were advanced in this study for two reasons. First, this study was descriptive and exploratory not hypothesis testing in nature. Second, even a cursory examination of the literature provides insufficient evidence that compliance issues have been clearly described in groups 'at-risk' for developing secondary health complications as a function of poor weight-control.

Methods

Participants and Study Design

Purposive sampling was used to enroll women (n = 15) from CWLP's into Project D.I.N.E.S. (Dietary Intake, Nutrition, & Exercise Study). Project D.I.N.E.S. is an ongoing research initiative designed to examine behavioral and motivational issues reported by people who use CWLP in an attempt to reduce (or control) their body weight. Demographic information for participants is provided in Table 1. Using a longitudinal cohort design (Vogt et al., 2012), each participant was asked to provide data using two digital tracking devices each day throughout a fixed monitoring period. The monitoring period lasted a total of seven consecutive days. No intervention was deployed to change either dietary intake or physical (in)activity behaviours during the monitoring period.

Instruments

Demographics: Each participant was asked to provide select demographic information (e.g., age, sex, etc.; see Table 1 for details).

Table 1: *Demographics, anthropometrics, and program designation of study participants.*

Variables	*Mean* (±*SD*) or Percent
Age (yrs)	44.3 (±15.6)
Marital Status	
Married/Common-Law	53.3%
Single/Divorced/Widowed	46.7%
Educational Qualifications	
High School/Equivalent	46.7%
University/Graduate School	53.3%
Employment Status	
Employed (Full/Part-Time)	86.7%
Not Employed	13.3%
Ethnicity	
Caucasian/White	93.3%
Asian	6.7%
Height (cm)	160.0 (±10.0)
Weight (kg)	82.3 (±21.0)
BMI ($kg \cdot m^{-2}$)	30.9 (±7.6)
BMI Classifications	
Normal Weight	26.7%
Overweight	20.0%
Obese	53.3%
CWLP Enrollment	
Weight Watchers®	60.0%
Herbal Magic®	6.7%
T.O.P.S.®	13.3%
Other	20.0%

Note: *SD* = Standard Deviation. *BMI* = Body Mass Index. BMI classifications are based on the cut-points established by Health Canada (2003) for use with adults. T.O.P.S. = Take Off Pounds Sensibly®.

Height/Body Weight: Height was measured using a wall-mounted stadiometer to the nearest 0.1 cm (Seca, Chino, CA, USA) and body weight was assessed using a digital weighing scale to the nearest 0.01 kg (Tanita WB-100A, Arlington Heights, IL, USA).

Physical Activity: Participants were asked to wear a SenseWear™ Armband (SWA™; BodyMedia Inc., Pittsburgh, PA, USA) for the duration of the monitoring period except when engaged in water-based activities (e.g., bathing, swimming, sauna, etc.). The SWA™ is a lightweight, portable, compact, motion detection device that is worn on the posterior facet of the left arm situated between the acromion and olecranon processes. Each SWA™ is comprised of a biaxial accelerometer (longitudinal and transverse planes), two heat sensors that sit flush against the outer layer of the skin, and a galvanic skin response sensor to monitor physical (in)activity. These sensors activate the SWA™ based on skin contact and heat flux. A standard USB port is used to transfer data from the SWA™ to a computer software program (i.e., InnerView Professional Software Version 5.1; BodyMedia Inc.) that contains algorithms designed to calibrate values for energy expenditure (total, active, and resting), METS, total number of steps, duration of physical activity and sleep, plus time spent laying down. Total duration of wear time is also provided by the SWA™ in terms of the number of minutes the device is worn on the body. The SWA™ armband has been widely used in research to gauge energy expended in free-living activity by overweight/obese adults (e.g., Shuger et al., 2011; St-Onge et al., 2007).

Dietary Intake. Participants used a Caloriesmart© Handheld Calorie Counter (C-CS100s™, Coheso, Pleasanton, CA, USA) to record their dietary intake. The C-CS100s™ is a small (63.5 mm × 109.2 mm

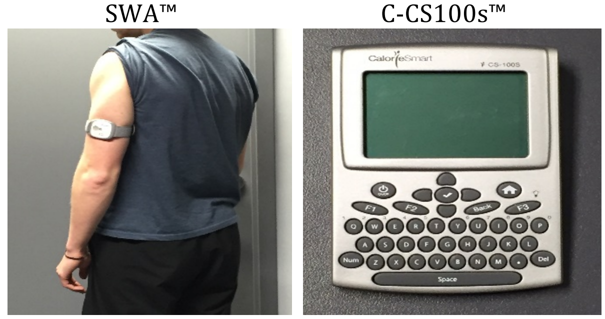
× 2.5 mm), portable, digital monitoring device commercially manufactured with a full QWERTY keypad plus an LED display that can be used to record dietary intake (and exercise). Each C-CS100s™ device was pre-loaded with a searchable database including nutrition content for over 50,000 food items (including brand name foods and items commonly offered in restaurants located throughout the United States of America and Canada). Study participants could impute up to 1000 personal meal options not included in the searchable database. Each device contains a standard USB port for data transfer to a windows-based software program.

Data Collection and Data Analysis

Following clearance from a university-based Research Ethics Board, participants reported individually to a research lab for an orientation session where they received a brief overview of the study and had an opportunity to ask questions of the study investigators. Each participant gave written informed consent before completing a self-report questionnaire. A C-CS100s™ and a SWA™ device (see Figure 1) was provided to each participant for use during the monitoring period along with a brief demonstration on how to use the device for the purposes of this study. A user guide for troubleshooting common issues with device use was provided to each participant during the orientation session. The SWA™ device was personalized with each participant's height, weight, sex, age, smoking status, and handedness at the outset/culmination of the monitoring period prior to data extraction as per manufacturers' guidelines. A reminder email was distributed on the 3rd day of the monitoring period for each participant to charge the SWA™ with a USB connector provided at the orientation session to prevent data contamination/loss as a function of low electrical power to the device. On the seventh day of the monitoring period, each participant returned to the lab with both devices. Data from both devices were extracted using software provided by the manufacturer specific to each device and stored electronically. Participants were thanked for their involvement in the study at the culmination of the monitoring period and provided a summary report via email 2 weeks after completing the study that included their personal data extracted from the C-CS100s™ and SWA™ devices.

Figure 1. Digital monitoring technology devices used in Project D.I.N.E.S.

SWA™ C-CS100s™



Data analyses followed an iterative process. First, the data were screened for any missing values and/or out-of-range responses. Second, compliance rates were calculated for the C-CS100s™ device using this formula: Σ [(Meal #1) + (Meal #2) + (Meal #3)]/21 × 100.0 percent (where Meal #1 = Breakfast/Day, Meal #2 = Lunch/Day, and Meal #3 = Dinner/Day entered within the C-CS100s™). Snacks were also recorded in the C-CS100s™ but not used in estimating compliance rates due to the high intra-individual variability expected with snacking behaviour. Compliance rates are expressed as the percentage of meals recorded using the C-

CS100s™ device across the monitoring period. Compliance rates for the SWA™ are expressed in (a) minutes/day of wear time determined as time spent with the device activated on the participant's body (Table 2) and (b) a percentage of on-body wear time expressed as a function of the total number of available hours (i.e., 168 $hr \cdot wk^{-1}$) the SWA™ was worn during the monitoring period (Table 3).

Results

No out-of-range responses were noted on any study variable. Zero days of missing data were evident for the wear time provided by the SWA™ and no perpetually blank records (i.e., 7 consecutive days with zero designated meal entries) were evident within the data extracted from the C-CS100s™.

Data for the breakfast, lunch, and dinner entries made within the C-CS100s™ plus the on-body wear time extracted from the SWA™ approximated a normal distribution although lunch and dinner entries were mildly leptokurtic (Table 2). Breakfast entries were made less frequently, on average, than either lunch or dinner entries using the C-CS100s™ device. Compliance rates per study participant (see Table 3) for use of the C-CS100s™ device ranged from 28.6 to 100.0% during the monitoring period (*Mean* = 85.4 ± 18.0%). Closer inspection of the data indicated that 93.3% of the participants using the C-CS100s™ device reported compliance rates that met (or exceeded) 75.0% of the expected designated meal entries (i.e., n_{meals} = 21) requested during the monitoring period.

On-body wear time for the SWA™ demonstrated considerable individual variability across participants during the monitoring period ranging from 29.6 to 85.4% of the total number of available hours for device use (*Mean* = 70.8 ±17.9%; Table 3). Overall, the on-body wear time for the SWA™ armband exceeded, on average, 19.00 $hr \cdot d^{-1}$ across the study monitoring period. Further evaluation of the on-body wear time extracted from the SWA™ indicated that 20.1% of this sample wore the SWA™ armband for less than 50.0% of the available hours of wear time requested within the monitoring period. A large portion of this sample (46.9%) wore the SWA™ for more than 80.0% of the available wear time hours encapsulating the 7-day monitoring period.

Table 2: *Descriptive statistics for all variables pertaining to the C-CS100Ss™ and SWA™.*

Variables	*Mean*	*SD*	*Skew.*	*Kurt.*
C-CS100s™				
Breakfast	5.7	1.6	-1.2	0.7
Lunch	6.1	1.3	-2.5	7.6
Dinner	6.1	1.4	-2.3	5.9
Total	17.9	3.8	-2.4	7.5
SWA™				
$\text{Total}_{\text{WearTime}}$	118.9	30.1	-1.4	0.7
$\text{Average}_{\text{WearTime}}$	19.1	4.9	-1.3	0.6

Note. *SD* = Standard Deviation. *Skew.* = Univariate Skewness. *Kurt.* = Univariate Kurtosis. C-CS100s™ entries per designated meal were summed over 7-d monitoring period. Average wear time for the SWA™ was calculated using the following expression in this study: Total Wear Time ($hr \cdot 7\ d^{-1}$).

Discussion

The purpose of this study was to examine compliance issues stemming from the use of two digital tracking devices manufactured commercially to monitor weight-control behaviours. Specifically, this descriptive study aimed to address the following research question: What are the compliance rates associated with simultaneous use of two digital technology devices manufactured to monitor weight-control behaviours?

Table 3: *Individual compliance rates for using the C-CS100s™ and SWA™ devices across 7-days.*

Participant	*C-CS100s™*	*SWA™*
1	*90.5*	*69.1*
2	*100.0*	*62.3*
3	*85.7*	*44.4*
4	*76.2*	*79.2*
5	*85.7*	*85.4*
6	*80.9*	*42.1*
7	*76.2*	*83.3*
8	*95.2*	*29.6*
9	*28.6*	*75.6*
10	*95.2*	*82.1*
11	*76.2*	*84.2*
12	*95.2*	*75.2*
13	*95.2*	*80.4*
14	*100.0*	*84.3*
15	*100.0*	*83.3*
Mean	*85.4*	*70.8*
SD	*18.0*	*17.9*
Range	*71.4*	*55.8*

Note: *SD* = Standard Deviation*.* *Range* = Highest Score – Lowest Score*.* Values in the table are expressed as percentages only.

Using a sample of CWLP users within a longitudinal cohort design (Vogt et al., 2012), this study provides evidence attesting to the degree of variability across persons evident when using multiple devices produced by commercial manufacturers to digitally monitor physical (in)activity and dietary intake behaviours. Marginally better compliance rates were noted with the handheld C-CS100s™ than observed with the SWA™ armband in this sample of CWLP users. Overall, the degree of imperfection evident in the compliance rates coupled with the short duration of the study monitoring period questions the viability of digital technology as a mechanism to promote optimal self-monitoring of weight-control behaviours, even in cohorts such as those using CWLP for whom self-regulation of weight-control behaviours is a paramount concern.

Examination of the compliance data reported in Tables 2 and 3 showcase the key finding from this study – namely that, on average, most CWLP users who enrolled in Project D.I.N.E.S. complied with device usage recommendations for both the C-CS100s™ and SWA™ over the monitoring period. It is also evident from the data reported in Table 3 that only 20% of CWLP users recruited into this phase of the study were able to provide entries for all designated meal times expected during the study monitoring period. Issues of individual preferences (e.g., not eating breakfast daily) coupled with any unforeseen (and unreported) challenges with using the C-CS100s™ device notwithstanding, it is concerning that most of this sample failed to report all designated meal entries over a short monitoring period thus yielding imperfect compliance rates. It is plausible that individual eating habits precluded (or exceeded) the designated meal entries requested in this phase of Project D.I.N.E.S. yet this assertion is speculative. This concern is further exacerbated when looking at the compliance rates for the SWA™ armband where less than half of the CWLP users studied in this phase of Project D.I.N.E.S. wore the device for at least 80.0% of the available wear-time hours over 7 d. Considering that tracking calories ingested (via dietary intake) and expended (via physical activity) remain hallmarks of successful weight-control programs, it seems reasonable to suggest based on the results of this small-scale study that caution is warranted before advancing digital technology as a panacea to optimize weight-control behaviours. Our findings imply that future studies embracing digital technology as an intervention platform to optimize weight-control behaviors systematically track and explicitly report compliance data pertaining to device usage.

The observation that compliance rates were marginally better for use of the C-CS100s™ handheld device compared with the SWA™ armband was not expected in this study yet seems worthy of commentary. One plausible explanation concerns the non-intrusive nature of the C-CS100s™ device as opposed to the SWA™ armband. Previous studies using the SWA™ armband report that discomfort associated with the device worn on the arm and minor skin irritations have been reported with adults classified as obese (e.g., St-Onge et al,. 2007). While no participant in this study reported perturbations in sleep activity or abrasions of the skin as a function of device use, it remains a possibility that these issues went unreported in this study and influenced compliance with use of the SWA™ armband. Future studies would do well to investigate this issue further. An alternative explanation concerns the similarity of the C-CS100s™ handheld device to other wireless handheld devices (e.g., smartphones) that are widely available and popular. Results of the Canadian Internet Use Survey (2012) indicated access to the internet by Canadians using wireless handheld devices akin to the C-CS100s™ has increased from 35.0 to 59.0% between 2010 and 2012. As such, it may be that the difference in compliance rates evident in this study is a function of 'device familiarity' associated with the C-CS100s™ experienced by users of CWLP providing data in this study. Irrespective of the underlying cause, it seems reasonable to contend that future studies not only report compliance data for digital technology but also attempt to identify factors that can facilitate/impede compliance with device use recommendations to advance health research.

The results of this study do nothing to undermine the potential for digital technology to aid self-monitoring attempts made by CWLP users seeking to track weight-control behaviours. Joint consideration of the work reported by Shaw et al. (2016) in combination with the findings of this study makes it apparent that challenges integral to gauging compliance issues linked with using digital technology are worth mentioning. One issue focuses on clearly demarcating 'compliant' from 'non-compliant/less-compliant' users within studies that employ digital technology to monitor weight-control behaviours. For example, considerable inconsistency in device wear time requirements is evident in studies of overweight/obese adults using the SWA™ armband with protocols ranging from 16 $hr \cdot d^{-1}$ (i.e., Shuger et al., 2011) to 22.8 $hr \cdot d^{-1}$ (i.e., St-Onge et al., 2007). Such inconsistences may, in part, stem from the inability of the SWA™ armband to work during aquatic-based activities which is a limitation of most electronic devices available to gauge physical (in)activity. Comparable limitations were evident with the C-CS100s™ device with reference to snacking behaviour recorded by study participants. Snacking does not represent a designated meal time (i.e., breakfast, lunch, or dinner) yet often features in a healthy approach to weight-control as a vehicle to manage cravings and satiate hunger. This renders the recording of snacking behaviour useful for understanding caloric intake yet challenging for calibrating compliance with device use recommendations between persons who never snack versus those who snack regularly across the day. Such limitations notwithstanding, it seems reasonable to suggest that clear and uniformly accepted guidelines classifying users as 'compliant' versus 'non-compliant/less-compliant' would be a useful next step for researchers with a vested interest in digital technology to consider.

Limitations of this study along with future directions are in order to advance the study of digital technology used to monitor weight-control behaviors. First, this study was limited to using two commercial devices that did not include smartphone applications. Future studies examining compliance issues with other devices focused on weight-control behaviors particularly those with smartphone use 'platforms' seems in order to augment the generalizability of our findings. Second, this study utilized a longitudinal design that featured a monitoring period lasting 7 consecutive days. Understanding the impact of shorter versus longer monitoring periods on compliance issues (e.g., device fatigue, user boredom, etc.) could be useful in terms of understanding long-term usability of digital monitoring technology. Third, no feedback was given to the participants by the research team during the monitoring period. Future studies including components of feedback (e.g., delayed versus real-time, etc.) may be useful in terms of fully explicating the role of digital monitoring technology in managing weight-control behaviours. Finally, this study used a sample of CWLP users who represent merely a portion of the population for whom weight-control remains a challenging issue. Future studies would do well to examine compliance issue in alternative cohorts deemed 'at-risk' for secondary health complications resulting from poor weight-control (e.g., men, obese children, etc.).

Conclusions

Digital technology produced by commercial manufacturers may be a useful intervention strategy to promote individual self-monitoring of weight-control behaviours yet compliance with device use recommendations varies widely among patrons of CWLP even over short durations of time. Variation in compliance rates, especially when using multiple devices (Shaw et al. 2016), is not a novel finding albeit this study may be the first to illustrate this phenomena in CWLP users who presumably have a vested interest in optimizing weight-control.

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Authors' Qualifications

The study authors' qualifications are as follows: Philip M. Wilson (B.Sc., M.Sc., PhD); Diane E. Mack (B.A., M.A., PhD); Chris M. Blanchard (B.A., M.A., PhD).

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