Original Article
CLINICAL TRIALS AND INVESTIGATIONS

Obesity

Relationship of Consistency in Timing of Exercise Performance and Exercise Levels Among Successful Weight Loss Maintainers

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Objective: This study aimed to evaluate whether consistency in time of day that moderate- to vigorous-intensity physical activity (MVPA) is performed relates to MVPA levels among successful weight loss maintainers in the National Weight Control Registry.

Methods: Participants (n = 375) reporting MVPA on ≥ 2 d/wk completed measures of temporal consistency in physical activity (PA) (> 50% of MVPA sessions per week occurring during the same time window: early/late morning, afternoon, or evening), PA levels, PA automaticity, and consistency in cues underlying PA habit formation (e.g., location).

Results: Most (68.0%) participants reported temporally consistent MVPA. These individuals reported higher MVPA frequency (4.8 ± 1.6 vs. 4.4 ± 1.5 d/wk; P = 0.007) and duration (median [IQR]: 350.0 [200.0-510.0] vs. 285.0 [140.0-460.0] min/wk; P = 0.03), and they were more likely to achieve the national MVPA guideline (≥ 150 min/wk) than temporally inconsistent exercisers (86.3% vs. 74.2%, P = 0.004). Among temporally consistent exercisers, 47.8% were early-morning exercisers; MVPA levels did not differ by time of day of routine MVPA performance (P > 0.05). Greater automaticity and consistency in several cues were related to greater MVPA among all participants.

Conclusions: Most participants reported consistent timing of MVPA. Temporal consistency was associated with greater MVPA, regardless of the specific time of day of routine MVPA performance. Consistency in exercise timing and other cues might help explain characteristic high PA levels among successful maintainers.

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Introduction

Regular physical activity (PA) is associated with long-term weight loss maintenance and numerous health benefits (1-4). Despite this, many individuals with obesity, including those who have undergone lifestyle or surgical intervention for weight loss, have difficulty meeting guidelines for the minimal amount of PA to improve health (150 min/wk of moderate- to vigorous-intensity PA [MVPA]) (5), let alone the higher amount recommended for promoting long-term weight loss maintenance (>250 min/wk of MVPA) (1,2,6-8). Thus, there is a need to identify novel strategies to help individuals with obesity adopt and sustain a high level of regular MVPA.

Traditional theories of PA behavior change often emphasize reflective, conscious influences on PA, such as perceived behavioral control and self-efficacy (9,10). However, a growing body of research also supports the influence of nonconscious processes, such as habit (i.e., automatic behavioral responses to environmental cues), on PA behavior (10-12). Therefore, there is a need to better understand how underlying markers of habit relate to PA behavior and can be leveraged to facilitate PA habit formation and maintenance. Repeated performance of PA in consistent contexts is posited to be critical to PA habit formation (12-15). Repeatedly exercising in the presence of consistent cues, such as at the same time of day or in the same location, may help to establish cue-exercise relationships (13,14). For example, through consistently exercising immediately after work, leaving work may become paired with going to the gym. Strong cue-behavior associations increase the habitual nature and automaticity (i.e., performance with lowered conscious awareness or volition) of PA, thus reducing the day-to-day attention, effort, and motivation required to perform PA (11,16-18).

Repeated performance of PA at the same time of day, or temporal consistency in PA, may be one important cue for forming and maintaining a PA habit. In contrast, exercising at variable times of the

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day, or temporal inconsistency, may less strongly support PA habit and automaticity, as there are fewer opportunities to establish time-based cued associations for PA. Temporal consistency in PA may also help to protect time for exercise in individuals' schedules, which could be critical for fostering a high PA level given that lack of time is a commonly cited barrier to PA (19). In addition to the potential importance of temporal consistency or inconsistency for PA levels, the particular time of day that PA is performed might also have implications for weight management. While research in this area has been limited, one study found that older women who were more active in the morning were at lower risk for obesity (20), and another found that adults who performed a greater proportion of their PA in the morning more successfully increased PA prior to bariatric surgery (21). Although these findings are initially supportive of the importance of morning PA, there is a need for additional research. For example, past research has not differentiated between performing PA early versus later in the morning. Exercising first thing in the morning may be especially conducive to fostering a PA habit, as waking up may serve as a cue for initiating this behavior. Exercising shortly after waking and before other obligations have a chance to interfere with PA plans may also facilitate greater PA levels. Additionally, preliminary research indicated that there may be physiological benefits of early-morning exercise for weight control (22). Further examination of the relationship between PA timing and PA levels, including differentiating the potential importance of early- versus late-morning exercise, is warranted.

The National Weight Control Registry (NWCR) (http://www.nwcr.ws/) was created to examine the characteristics and behavioral patterns of successful weight loss maintainers. Over the past two decades, studies of NWCR participants have shown that those who are most successful in maintaining their weight loss also tend to be more consistent in performance of weight-related behaviors, including adhering to the same dietary regimen and regularly self-monitoring weight (23-25). NWCR participants are, on average, also a highly physically active group, engaging in approximately 40 min/d of objectively measured MVPA (26). However, to what extent temporal or cue consistency, automaticity, and timing of PA play a role in NWCR participants' high MVPA levels is not known. The NWCR provides a unique resource to evaluate associations of PA temporal or cue consistency, automaticity, and timing with MVPA in a highly active population who has successfully achieved and maintained substantial weight loss. Results could have implications for the development of novel strategies to achieve higher PA levels, such as recommending PA performance at a specific time of day or use of specific cues to establish a PA habit (27,28).

Among NWCR participants who reported MVPA on multiple days per week, the present study evaluated (1) differences in the proportion who were temporally consistent (i.e., majority of MVPA sessions occurring during the same time window: early morning, late morning, afternoon, or evening) versus temporally inconsistent exercisers, (2) whether MVPA levels differed among temporally consistent and temporally inconsistent exercisers, (3) whether the specific time of day of exercise among temporally consistent exercisers related to MVPA levels, and (4) associations of MVPA with reported PA automaticity and consistency in PA cues (time, people, activity, routine, location, and mood) among all participants. We hypothesized that (1) a majority of participants would be temporally consistent exercisers, (2) temporally consistent exercisers would report greater MVPA frequency and duration compared with temporally inconsistent exercisers, (3) early-morning temporally consistent exercisers would report the highest MVPA levels, and (4) greater PA automaticity and cue consistency would relate to greater MVPA.

Methods

Participants

Eligibility criteria for the NWCR include age ≥ 18 years and weight loss ≥ 30.0 lb maintained for ≥ 1 year. Weight loss is verified by physician documentation, before and after photos, or collateral report from family or friends. Eligibility for the present study further required (1) reporting ≥ 2 d/wk of MVPA on a validated measure of PA and (2) providing valid responses on a measure of temporal consistency in MVPA performance.

Procedure

Registry members are recruited on an ongoing basis through advertisements in local and national media outlets and via the NWCR website. Following admission to the NWCR, participants are sent a baseline questionnaire and follow-up questionnaires once per year. Compensation is not provided. While the NWCR has enrolled more than 10,000 participants, only those who completed an annual questionnaire since July 2018, when the PA timing and habit measures were added to the assessment battery, were eligible to contribute to the present analysis. All procedures were approved by The Miriam Hospital Institutional Review Board.

Measures

Consistent and inconsistent exerciser status. To assess temporal consistency in exercise, participants were asked to respond to the item, "When I exercise, it tends to be at the same time of day." Response options were "true," "false," or "I don't exercise." If participants responded "true," they then reported the start time of their exercise, if any, for each of 7 days in a typical week. Participants were instructed to report only on exercise for which they specifically set aside time to be physically active for the purpose of improving health, that was ≥ 10 consecutive minutes in duration, and that made them breathe harder than normal. Participants were instructed to report the start time of their longest MVPA session if they typically engage in multiple exercise sessions on a given day.

Participants were classified as temporally inconsistent exercisers if they reported that they do not tend to exercise at the same time of day by answering "false" to the temporal consistency item. Participants were classified as temporally consistent exercisers if (1) they answered "true" and (2) > 50% of their reported exercise sessions across a typical week fell within one of the following time windows: early morning (4:00-8:59 AM), late morning (9:00-11:59 AM), afternoon (12:00-4:59 PM), or evening (5:00 PM-3:59 AM). If participants endorsed temporally consistent exercise but then reported a temporally inconsistent exercise pattern (≤ 50% of exercise sessions occurring in the same time window; 50% of exercise sessions in one time window and 50% in another), they were categorized as temporally inconsistent exercisers. Thus, participants exercising 2 d/wk had to report both exercise sessions within the same time window to be categorized as temporally consistent, individuals exercising 3 d/wk had to report ≥ 2 exercise sessions within the same window, individuals exercising 4 d/wk had to report ≥ 3 exercise sessions within the same window, and so on. This categorical timing scheme was modeled off of prior studies (20,21). However, as noted, we further differentiated early- and late-morning exercisers because of potential biological (22) and behavioral benefits of early-morning PA.

PA. PA was assessed with the Paffenbarger Physical Activity Questionnaire (29). The following three indices of PA were derived based on participant responses: (1) number of days of MVPA per week, (2) total minutes of MVPA per week, and (3) whether or not each individual was meeting the national health recommendation of 150 min/wk of MVPA (5). To determine number of days of MVPA per week, participants first responded "yes" or "no" to the following question on the Paffenbarger: "In general, at least once per week, do you engage in regular activity similar to brisk walking, jogging, bicycling, etc., long enough to work up a sweat, get your heart thumping, or get out of breath?" Responses of "no" were coded as 0 days of MVPA per week. If participants answered "yes," they then reported the number of days per week on which they engage in exercise of the described intensity.

Consistent with prior research (30), total minutes of MVPA per week were determined by summing (1) total reported minutes per week spent brisk walking in bouts of ≥ 10 minutes for the purpose of exercise or transportation and (2) total reported minutes per week spent performing other sport, fitness, or recreational activities of a moderate or vigorous intensity, as determined by Paffenbarger scoring guidelines (29). This total MVPA minutes per week variable was also used to determine whether participants were achieving 150 min/wk of MVPA.

Cue consistency. Cue consistency for PA was assessed by asking participants to report their agreement with six statements, each of which assessed consistency in a specific cue for PA (31). Each item began with the stem, "Each time I exercise…" and was followed by a description of the potential cue as follows: "…it is the same time of day" (time of day), "…I am around the same people" (people present), "…I am doing the same type of exercise" (exercise type), "…I am in the same part of my daily routine" (timing in routine), "…I am in the same place" (location), and "…I am in the same mood" (mood). Participants rated their agreement with each statement from 1 (not true at all) to 7 (very true). Each item was examined separately in analyses.

Exercise automaticity. A slightly modified version of the four-item Self-Report Behavioral Automaticity Index (32), which is a validated subscale of the Self-Report Habit Index (16,33), assessed exercise automaticity. Participants read the stem, "Engaging in regular exercise (i.e., being physically active for the purpose of improving your health for at least 10 consecutive minutes) is something…" and then responded to four items assessing automaticity as follows: "…I do automatically," "…I do without having to consciously remember," "…I do without thinking," and "…I start doing before I realize I'm doing it." As in previous research, the stem was modified slightly to be specific to the behavior of interest (regular exercise). Responses were provided on a scale of 1 (never) to 4 (always). While this 4-point scale has been used in prior research (34), most studies have used a 5- or 7-point scale (11,16,32). Responses were averaged to create a composite score. In the present study, Cronbach ∝ for the 4-item measure = 0.87.

Other measures. Current height and weight (to calculate BMI), age (from birth date), gender, race, employment status ("Are you currently working for pay full or part time?": yes/no), highest and lowest weight (to determine maximum weight loss), and duration of weight loss maintenance (based on month/year since first losing ≥ 30 lb) were assessed via questionnaire.

Statistical approach

Data were analyzed in SPSS Statistics version 25 (IBM Corp., Armonk, New York). Significance level was set at $\alpha = 0.05$. Data were examined for missingness, normality, and outliers. The distribution of total minutes of MVPA per week was not normally distributed, nor were the distributions of scores for cue consistency items. Nonparametric tests were thus used where appropriate. While several outliers were identified for total minutes of MVPA per week, original values were used in analyses given the rank-based nature of nonparametric analyses.

The proportion of NWCR participants identifying as temporally consistent or inconsistent exercisers was reported as the number of participants in each category with percentages. A one-way ANOVA was used to examine potential differences between temporally consistent and temporally inconsistent exercisers, as well as between temporally consistent exercisers by specific time window for exercise (early morning, late morning, afternoon, evening), on number of MVPA days per week. Post hoc tests with a Bonferroni correction were used to examine between-group differences where appropriate. Nonparametric Kruskal-Wallis H tests were used to examine differences between temporally consistent and temporally inconsistent exercisers and between temporally consistent exercisers by specific time window for exercise on total minutes of MVPA per week. χ^2 analyses were used to compare the proportion of temporally consistent and temporally inconsistent exercisers, as well as the proportion of temporally consistent exercisers by specific time window for exercise, meeting the public health recommendation of 150 min/wk of MVPA. The associations of MVPA with PA automaticity and each cue consistency item were assessed using Pearson correlations (for variables with a normal distribution) or Spearman rank correlations (for variables with a non-normal distribution). For ease of interpretation, P values from Kruskal-Wallis tests are presented with median and 25th and 75th percentile values rather than ranked scores.

Results

Sample characteristics

A total of 509 NWCR participants completed PA timing and habit measures, of whom 375 (73.4%) met study inclusion criteria. Of those excluded, 128 were excluded for reporting < 2 d/wk of MVPA, and 6 were excluded for providing inadequate information on the temporal consistency measure to characterize their PA temporal consistency pattern. Excluded individuals had a higher mean BMI ($F = 16.2$, $P < 0.001$) and were more likely to identify as female ($\chi^2 = 4.3$, $P = 0.04$) compared with eligible participants. Table 1 presents sociodemographic and anthropometric characteristics for the full sample ($n = 375$) and for temporally consistent and inconsistent exercisers. Of the 375 participants retained for analysis, 255 (68.0%) individuals were categorized as temporally consistent exercisers, and 120 (32.0%) were categorized as temporally inconsistent exercisers. Temporally consistent and inconsistent exercisers did not differ on any sociodemographic or anthropometric characteristics. On average, participants were female, middle-aged, and employed, identified as white, and had BMI in the overweight range.

TABLE 1 Sociodemographic and anthropometric characteristics and MVPA levels for full sample and temporally consistent and inconsistent exercisers

	Full sample ($N=375$)	Temporally consistent exercisers ($n=255$)	Temporally inconsistent exercisers ($n=120$)	Comparisons between temporally consistent and inconsistent exercisers (P)
Sociodemographic and anthropometric characteristics				
BMI (kg/m^2)	26.5 (4.8)	26.6 (5.0)	26.2 (4.3)	0.56
Age (y)	53.4 (14.0)	53.5 (13.9)	53.3 (14.3)	0.94
Gender (% female)	64.8%	62.9%	68.6%	0.32
Race (% white)	95.2%	95.7%	94.2%	0.57
Work status				
Employed	76.0%	76.1%	76.0%	0.98
Not employed	24.0%	23.9%	24.0%	
Maximum weight loss (lb)	83.7 (38.3)	85.0 (41.3)	81.2 (31.3)	0.41
Time weight loss maintained (y)	7.4 (5.5)	7.1 (4.7)	8.0 (7.0)	0.15
MVPA levels				
MVPA days per week	4.7 (1.6)	4.8 (1.6)	4.4 (1.5)	0.007
Weekly MVPA minutes	325.0 (180.0, 495.0)	350.0 (200.0, 510.0)	285.0 (140.0, 460.0)	0.03
Proportion meeting 150-min/wk recommendation	82.4% ($n=309$)	86.3% ($n=220$)	74.2% ($n=89$)	0.004

Means (SD) are presented for continuous sociodemographic/anthropometric data and MVPA days per week, medians (25th, 75th percentile) are presented for weekly MVPA minutes, and percentages are presented for categorical data. Data missing for BMI ($n=2$), age ($n=61$), gender ($n=60$), race ($n=62$), work status ($n=62$), and weight loss history ($n=57$); percentages are for available data.

Differences in MVPA between temporally consistent and temporally inconsistent exercisers

As shown in Table 1, temporally consistent exercisers reported performing MVPA on more days per week and for more total minutes per week compared with temporally inconsistent exercisers. Additionally, a greater proportion of temporally consistent versus temporally inconsistent exercisers reported meeting the 150-min/wk PA guideline.

Specific timing of exercise among temporally consistent exercisers

Table 2 presents the distribution of early-morning, late-morning, afternoon, and evening exercisers; sociodemographic and anthropometric characteristics for each exercise group; and MVPA levels by exercise group. Of note, nearly half (47.8%) of temporally consistent exercisers were early-morning exercisers. Exercise groups differed on age, with evening exercisers being younger than all other exercise groups; race, with fewer evening exercisers identifying as white compared with early-morning exercisers; and employment status, with more evening exercisers being employed compared with late-morning exercisers. Exercise groups did not differ on MVPA levels.

Automaticity and cue consistency

Associations of PA automaticity and PA cue consistency with MVPA levels were evaluated among all participants ($n=375$). As shown in Table 3, greater exercise automaticity and greater consistency in all cues except the people present during exercise were associated with more MVPA days per week. Only exercise automaticity and consistency in time-based cues (of day and in routine) were related to minutes of MVPA per week, however.

Discussion

This study is the first to evaluate the relationship between temporal consistency of exercise, including the specific time of day it is performed, with MVPA levels among successful weight loss maintainers. As hypothesized, most participants (68.0%) were consistent in the timing of their MVPA performance, with early morning being the most common time of day that exercise was routinely performed. Temporally consistent exercisers reported higher weekly MVPA frequency and duration, including greater likelihood of meeting the national PA guideline, compared with temporally inconsistent exercisers. These findings align with past research indicating that NWCR members are, on average, highly consistent in performance of weight control behaviors and that greater consistency in particular weight management behaviors may be associated with more successful long-term outcomes (23-25). Although the cross-sectional design precludes the ability to determine direction of causality, one possible interpretation of these data is that temporal consistency in PA could be beneficial for forming PA habits and fostering a high level of PA. For example, individuals who routinely perform PA at the same time of day may develop stronger cue-behavior relationships and greater PA automaticity than individuals with a

TABLE 2 Sociodemographic and anthropometric characteristics and MVPA levels among temporally consistent exercisers based on time of day of exercise

	Early-morning exercisers (n = 122; 47.8%)	Late-morning exercisers (n = 40; 15.6%)	Afternoon exercisers (n = 29; 11.4%)	Evening exercisers (n = 64; 25.1%)	P
Sociodemographic and anthropometric characteristics					
BMI (kg/m^2)	25.9 (4.2)	26.8 (5.3)	26.5 (5.2)	27.7 (5.9)	0.16
Age (y)	53.9 (13.4)	60.5 (13.6)	58.7 (11.7)	46.4 (13.0)	<0.001
Gender (% female)	63.7%	64.5%	65.2%	59.3%	0.94
Race (% white)	99.0%	96.8%	95.7%	88.9%	0.03
Work status					0.04
Employed	77.2%	58.1%	73.9%	85.2%	
Not employed	22.8%	41.9%	26.1%	14.8%	
Maximum weight loss (lb)	81.7 (37.3)	85.1 (43.6)	93.2 (49.5)	87.4 (43.5)	0.63
Time weight loss maintained (y)	7.2 (4.4)	6.4 (3.7)	7.4 (3.7)	7.2 (5.8)	0.82
MVPA levels					
MVPA days per week	5.1 (1.7)	4.7 (1.8)	4.8 (1.4)	4.4 (1.5)	0.06
Weekly MVPA minutes	357.5 (223.8, 496.3)	319.0 (175.0, 480.0)	330.0 (180.0, 550.0)	355.0 (200.0, 547.5)	0.91
Proportion meeting 150-min/wk recommendation	88.5% (n = 108)	82.5% (n = 33)	82.8% (n = 24)	85.9% (n = 55)	0.73

Means (SD) are presented for continuous sociodemographic and anthropometric data and MVPA days per week, medians (25th, 75th percentile) are presented for weekly MVPA minutes, and percentages are presented for categorical data. Post hoc analyses for age: evening < early morning (P = 0.005), evening < late morning (P < 0.001), and evening < afternoon (P = 0.001); race (% white): evening < early morning (P = 0.004); work status (% employed): evening > late morning (P = 0.005).

temporally variable PA routine (13,27). Consequently, temporally consistent exercisers may be less vulnerable to day-to-day fluctuations in deliberate intentions for PA and achieve higher PA levels (18). Alternatively, it is also possible that individuals who engage in a regular, high level of MVPA happen to develop temporal consistency in their exercise routine over time. Additionally, factors other than temporal consistency, such as greater motivation for PA, may have influenced the observed relationships between temporal consistency and PA levels. Future research should further investigate these possibilities through randomized trials of PA timing (temporally consistent versus temporally variable) and examination of how temporal consistency in PA practice relates to other known predictors of regular PA (27).

Among those who reported a temporally consistent PA routine, early morning was the most common time that exercise was performed, followed by evening. In contrast with our hypothesis and previous work (20,21), the particular time of day at which temporally consistent exercisers most often performed PA was not differentially related to PA levels. Our findings thus add to the mixed literature on the optimal time of day, if any, for PA. Because all temporally consistent exercisers in the present study reported, by definition, exercising at the same time day to day, it is likely that these individuals had well-established PA routines. Perhaps among individuals who have already established a strong PA habit, the particular time of day at which PA is performed is less important than overall temporal consistency in PA. As indicated by prior research, however, morning PA performance may be especially important for initially developing a PA habit and for PA adoption (21). The finding that nearly half of temporally consistent exercisers were early-morning exercisers also suggests that performing PA in the early morning may be helpful for maintaining a regular PA routine, although these individuals were not more active than their counterparts in the present study and we cannot determine causality from the present data. It is worth noting that age, race, and work status were related to the specific timing of PA among temporally consistent exercisers, suggesting that broader individual and contextual factors (and not just environmental cues) affect PA timing. Future interventions attempting to promote PA using habit-based principles may benefit from acknowledging or even trying to capitalize on sociodemographic factors that may impact PA timing (e.g., for working individuals, targeting work as a PA cue).

As hypothesized, across all participants, greater reported automaticity of PA was associated with greater MVPA frequency and duration (11). Greater consistency in several cues also related to more MVPA days per week, while only consistency in time-based cues (of day and in routine) related to total accrued MVPA minutes. Overall, these findings align with models of PA behavior emphasizing nonconscious influences on PA performance (10,11) and highlight the potential utility of interventions that attempt to increase PA through using cues to increase the automaticity and habitual nature of PA (27). Additionally, these findings suggest that the cues most associated with how frequently one exercises may differ from those that influence exercise duration. Whereas consistency in a range of cues, such as location, type, and mood, may be helpful for prompting individuals to exercise, only consistency in time-based cues was related to number of MVPA minutes accrued during the week. This may indicate that setting aside a designated, consistent time for PA during the day is helpful not only for increasing the automaticity and regularity of PA performance but also perhaps for planning to exercise and successfully exercising for longer (35,36). These findings are consistent with past research that has differentiated between different

TABLE 3 Relationships between exercise automaticity, cue consistency, and PA

	Mean (SD) or median (25th, 75th percentile)	Correlation with exercise days per week	Correlation with MVPA minutes per week
Exercise automaticity	2.7 (0.9)	0.47***	0.42***
Cue consistency			
Exercise type	6.0 (5.0, 7.0)	0.18***	0.07
Exercise location	6.0 (5.0, 7.0)	0.18**	0.08
Timing in routine	6.0 (4.0, 7.0)	0.28***	0.21***
Time of day	6.0 (4.0, 7.0)	0.25***	0.18***
People present	5.0 (3.0, 7.0)	0.07	0.03
Mood	5.0 (4.0, 6.0)	0.16**	0.05

Mean (SD) is presented for exercise automaticity and medians (25th, 75th percentile) are presented for cue consistency items. Pearson correlation was used for exercise automaticity analyses, and Spearman correlation was used for cue consistency analyses.
*$P<0.05$.
**$P<0.01$.
***$P<0.001$.

phases of PA (e.g., instigation and execution; preparation and performance) and that has identified potentially distinct cues and levels of automaticity for each phase (37-39). While these findings should again be interpreted with caution because of their correlational nature, additional research on cues that influence different phases of PA appears warranted.

This was the first study to examine temporal consistency and other indicators of PA habit among a sample of successful weight loss maintainers. Research on habit-based aspects of PA is important given that many traditional theories of health behavior change and past PA interventions have paid relatively limited attention to nonconscious influences on PA (9). The NWCR is also an important sample in which to examine how timing of PA and PA habit may relate to MVPA performance given that NWCR participants on average engage in a high level of PA and the importance of PA for long-term weight loss maintenance. This study also has limitations. While the NWCR is a unique group for studying psychological characteristics and behavioral practices associated with successful weight management, many NWCR participants have maintained ≥ 10% weight loss for a decade or more (40), which is not representative of most individuals' weight trajectories following intentional behavioral weight loss (41). Additionally, entry into the NWCR is nonrandom and self-selected, and the NWCR is quite homogenous demographically. Findings may thus not generalize to other samples. MVPA was also self-reported. Self-reports of PA may be biased and subject to overestimation (6,42), and assessment of MVPA via questionnaire (versus accelerometer) may have impacted our ability to compare our findings to past work regarding the relation between specific time of day of PA and overall MVPA levels (20,21). Assessment occurred at only one time point. We therefore cannot draw firm conclusions as to the representativeness of participants' reported PA levels, patterns, and habits across a more extended time frame. Additionally, the temporal consistency measure was created for this study and thus needs further validation, and differences in scale anchors precluded comparisons of PA automaticity levels to past studies. Future studies are needed that use objective PA assessment and that study how markers of PA habit and PA timing relate to the behavioral adoption and maintenance of MVPA over a longer time period. Future research should also examine potential biological benefits of performing PA at certain times of the day. For example, there are mixed findings about the time of day at which PA may optimally influence blood sugar control (43-45).

Conclusion

This study found that successful weight loss maintainers who reported temporal consistency in PA engaged in more MVPA than maintainers with more temporally variable exercise routines. Additionally, greater automaticity and greater consistency in cues for PA were related to greater PA levels, especially regarding PA frequency during the week. While a large proportion of temporally consistent exercisers were early-morning exercisers, suggesting a potential benefit of early-morning PA for maintaining a regular PA routine, the specific time of routine PA (e.g., early morning vs. evening) among temporally consistent exercisers was not related to PA levels. Taken together, our findings suggest that exercising at the same time of day, regardless of whether it is during the morning, afternoon, or evening, may help with achieving higher PA levels. Future research is needed to clarify how the timing of PA relates to or may causally influence PA adoption versus maintenance and to identify the most effective intervention strategies for building a strong PA habit.

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