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Weight management behaviours mediate the relationship between weight cycling, BMI and diet quality among US Army Soldiers

Jillian T. Allen[1,2], Julianna Jayne[1], J. Philip Karl[1]*, Susan M. McGraw[1], Kristie O'Connor[1], Adam DiChiara[3] and Renee E. Cole[4]

[1]*Military Nutrition Division, US Army Research Institute of Environmental Medicine, Natick, MD 01760, USA*
[2]*Oak Ridge Institute for Science and Education, Belcamp, MD 21017, USA*
[3]*Natick Soldier Research Development and Engineering Center, Natick, MA 01760, USA*
[4]*US Military-Baylor University Graduate Program in Nutrition, Joint Base San Antonio-Fort Sam Houston, TX 78234, USA*

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Abstract
Weight cycling is prevalent in sports/professions with body composition standards, and has been associated with weight management behaviours that may contribute to suboptimal diet quality and weight gain. US Army Soldiers may be at increased risk of weight cycling relative to civilians due to mandated body composition standards. However, the relationship between weight cycling, weight management behaviours, BMI and diet quality among Soldiers is unknown. In this cross-sectional study, 575 Soldiers (89 % enlisted, 90 % male, 23 ± 4 years) at Army installations at Joint Base Elmendorf-Richardson, AK, Joint-Base Lewis McChord, WA, and Fort Campbell, KY completed questionnaires on food frequency, health-related behaviours and history of weight cycling (≥ 3 weight fluctuations ≥ 5 % body weight). Weight cycling was reported by 33 % of Soldiers. Those who reported weight cycling reported higher BMI (27 ± 4 *v.* 25 ± 3 kg/m^2, $P < 0{\cdot}001$) and higher prevalence of engaging in weight management behaviours prior to body weight screening but did not report lower dietary quality (Healthy Eating Index-2015 (HEI) scores 59 ± 10 *v* 59 ± 11, $P = 0{\cdot}46$) relative to those who did not report weight cycling. Results of mediation analyses suggested that weight cycling may affect BMI both directly ($c' = 1{\cdot}19$, 95 % CI: 0·62, 1·75) and indirectly ($ab = 0{\cdot}45$, 95 % CI: 0·19, 0·75), and HEI scores indirectly ($ab = 0{\cdot}69$, 95 % CI: 0·20, 1·35) through the adoption of weight management behaviours. Weight cycling is common in Soldiers and is associated with higher BMI and higher prevalence of engaging in weight management behaviours that mediate associations between weight cycling, BMI and diet quality.

Key words: Weight cycling: Eating behaviours: Body composition: Diet quality: Military

Weight cycling is characterised by 'repeated cycles of weight loss and regain' and is common among individuals who participate in sports or work in professions where a certain body weight or image must be maintained[1,2]. To lose weight quickly, individuals in these sports/professions often adopt behaviours such as restricting food intake, skipping meals or using extreme methods such as dehydration, sweat suits, saunas, diet pills, laxatives and vomiting[3,4]. While these behaviours can facilitate rapid weight loss, they may also compromise sport-specific performance[4] and contribute to metabolic adaptations that promote increased adiposity and weight regain[5] in excess of the amount of weight originally lost[6]. This may lead to multiple bouts of weight cycling that, over the long-term, increase risk of chronic diseases such as obesity, hypertension and type 2 diabetes[1,6–10].

US Army Soldiers may be at risk of adopting behaviours that promote weight cycling due to Army-specific body weight and composition standards and a military culture that stresses a 'soldierly' appearance (i.e. neat and fit professional image)[11,12]. All Soldiers are assessed bi-annually for adherence to these standards using a BMI-based screening. Those who exceed their maximum screening weight undergo a circumference-based body fat assessment to confirm compliance with mandatory body composition standards[12]. Soldiers who exceed these standards are enrolled in an Army-specific weight management programme that involves weight management counselling, monthly monitoring of weight and body fat, and includes punitive measures such as restriction from training opportunities or promotion until the Soldier becomes compliant with standards[13]. The incentive to comply is high as Soldiers who are unable to successfully meet the standards or have reoccurrences of failing standards can be involuntarily discharged from service[13].

Beyond body weight and composition standards, military culture emphasises notions that excessive body fat reflects lack

Abbreviations: HEI, Healthy Eating Index;; MEBS, Military Eating Behavior Survey.

* **Corresponding author:** J. Philip Karl, james.p.karl.civ@mail.mil

of personal discipline, distracts from a soldierly appearance and indicates poor health[10,14,15]. This emphasis is thought to contribute to body dissatisfaction and stigmatisation, which, in combination with body composition standards, may foster the adoption of eating behaviours such as over-restriction and binging[10,12,16]. These behaviors, in turn, have been associated with excess weight gain, stress, decreased occupational performance, and increased risk of injury and mental health disorders[17]. Indeed, US active duty military and veterans are at increased risk for weight cycling compared with civilians[10,12,16], and mean BMI of Soldiers has increased over the past 10 years with BMI trajectories suggestive of weight cycling apparent in the population[18]. Soldiers who show BMI fluctuations indicative of weight cycling have a higher incidence of failing body composition standards and are more likely to show a trajectory of weight gain *v* weight stability[18]. Thus, military standards and culture may promote weight cycling.

Nutrition is a key element in overall health, optimal body composition, physical and cognitive performance, psychological resilience, and recovery for military personnel[19–21]. Soldiers with higher diet quality are more likely to have normal body composition, Army Physical Fitness Test (APFT) scores in the top quartile and higher emotional fitness scores[19]. High-quality diets are also thought to support successful long-term maintenance of a healthy body weight and composition[22,23]. Whether or not weight cycling is associated with suboptimal diet quality in Soldiers has not been examined. However, if weight cycling in Soldiers is associated with poor diet quality, then improving the diets of these individuals may be one strategy to break the futile cycle. It has been proposed that dieting behaviours, especially behaviours such as periods of over-restriction that lead to episodic uncontrolled eating, are one explanation for the occurrence of weight regain after weight loss[24]. Since rapid weight loss may be achieved through weight management behaviours characterised by poor nutritional intake, it is important to consider how weight cycling, weight management behaviours, BMI and diet quality may be related.

Although the prevalence of overweight and obesity is lower among service members compared with civilian populations, rates among US military personnel demonstrate a continuing rise over the last two decades[18,25] and current estimates indicate that 17 % of USmilitary personnel have a BMI that classifies them as having obesity[25]. Recent findings have demonstrated that Soldiers of all ranks report experiencing several barriers within the Army eating environment that restrict behaviour change and the ability to make healthy choices[26]. Common barriers include lack of access to nutritious options, excess exposure to fast food, limited time to eat meals or prepare healthy foods, time constraints that promote fast eating, and increased exposure to stress/trauma compared with the civilian population[26,27]. Thus, overweight and obesity are increasingly common in US military personnel, and identification of contributing factors is needed to inform development of prevention strategies.

This cross-sectional study aimed to examine associations between weight cycling, weight management behaviours, BMI and diet quality in US Army Soldiers. We hypothesised that Soldiers who reported weight cycling would also report a higher prevalence of adopting weight management behaviours prior to body weight screenings and have a higher BMI and poorer diet quality than those who did not report weight cycling. Additionally, we hypothesised that being more likely to adopt weight management behaviours prior to body weight screening would mediate associations between weight cycling and BMI and weight cycling and diet quality, respectively.

Methods

Study design and population

From 2016 to 2017, 1789 Soldiers from eight Army installations were surveyed in person during the development and validation of the Military Eating Behavior Survey (MEBS)[28]. The MEBS contains military-relevant phrasing of questions assessing eating behaviours, mediators of eating behaviours, food and supplement intake, nutrition knowledge, history of weight management practices, current and past body weight, and demographics. Groups of Soldiers were selected by their command to be briefed in-person prior to completing the MEBS. All active-duty Soldiers who were ≥ 18 years of age, spoke English and had completed initial military training were eligible to participate. A subset of Soldiers (*n* 309) were intentionally enrolled during initial military training in order to capture individuals first being exposed to the military environment, culture, values and body composition requirements[28]. No additional inclusion/exclusion criteria were applied.

The MEBS development study was approved by the Institutional Review Board of the US Army Medical Research and Development Command, Fort Detrick, Maryland. Investigators adhered to the policies regarding the protection of human subjects as prescribed in Army Regulation 70-25 and the research was conducted in adherence with the provisions of 32 CFR Part 219. All Soldiers were assured of the confidentiality of their responses and provided written, voluntary informed consent.

The sample for the cross-sectional analyses reported herein is from 575 Soldiers (aged 18 to 42 years (mean ± SD 22·6 ± 3·4 year)) who completed the final version of the MEBS at Army installations at Joint Base Elmendorf-Richardson, AK (*n* 192), Joint-Base Lewis McChord, WA (*n* 98), Natick Soldier System Center, MA (*n* 31) and Fort Campbell, KY (*n* 254). In total, 607 Soldiers at these installations were briefed for potential participation, 577 of them provided informed consent and 575 completed the MEBS. From this same group of volunteers, a subsample of 446 Soldiers at Joint Base Elmendorf-Richardson, AK, and Fort Campbell, KY, were asked to complete a FFQ[27], of which 441 Soldiers agreed. A *post hoc* power analysis using G × Power[29] determined the sample size was sufficient for regression models with up to 10 predictors to detect an R^2 as small as 0·02 or an odds ratio of 1·2 with 80 % probability at a significance level of 0·05.

Dépendent variables

BMI and Healthy Eating Index score. BMI was calculated from self-reported height and weight. Height was captured by asking for 'Your height in feet and inches (without footwear)', and weight was captured by asking for 'Your current weight (without clothing in pounds)'. Biologically implausible values and outliers based on Army regulations for minimum and maximum height and weights[11] were excluded from the analysis (*n* 2). Self-reported height and weight have been shown to have a high correlation ($r = 0{\cdot}78$–$0{\cdot}88$) to measured values among Soldiers[30].

The Healthy Eating Index (HEI) is a validated measure of diet quality used to evaluate nutritional adequacy of the foods consumed based on food components included in the Dietary Guidelines for Americans (DGA)[31]. The HEI has been used to assess diet quality in both the general population and military populations[20,21,31]. HEI-2015 includes thirteen components that are scored based on their alignment with the 2015–2020 DGA recommendations. These component scores are based on adequacy of intake of total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids. Because these food groups are encouraged, higher scores of these components reflect more desirable dietary intake. Components that are scored based on moderate consumption include refined grains, Na, added sugars and saturated fats. Higher scores for these components reflect lower intake due to the DGA recommendation to limit consumption. Each component can be scored independently and can also be evaluated together to assess overall diet quality, which is reflected by the total HEI score. The total HEI scoring system ranges from 0 to 100, with higher scores reflecting more optimal diet quality[31,32]. To facilitate interpretation, HEI-2015 scores are assigned letter grades, with scores between 90 and 100 interpreted as a grade of A, 80 to 89 a B, 70 to 79 a C, 60 to 69 a D and 0 to 59 an F[32]. HEI-2015 total scores were calculated from the validated Block 2014 FFQ[33] which assesses frequency of food and beverage intake over the past 6 months. Paper copies of the FFQ were administered along with photographs for portion size estimations. The study team, led by a Registered Dietitian, provided instruction and was available to answer questions. Questionnaires were analysed for macro- and micronutrient intakes, and HEI total and component scores by Nutrition Quest (Berkeley, CA, USA) using the US Department of Agriculture Food and Nutrient Database for Studies version 1.0.

Independent variables

Self-Reported weight cycling. Similarly to others, weight cycling was defined as ≥ 3 events of weight fluctuations[18,32], as determined by the question 'During your military career, how many times has your weight gone up AND down by more than 5 % of your body weight (excluding pregnancy or illness)?', to create a dichotomous variable for self-reported weight cycling (yes or no). To improve ability to identify 5 % changes in body weight, examples were provided for eight body weights ranging between 120 and 300 pounds. Socio-demographic variables were used to determine Soldier characteristics and used as control variables in analyses. Specifically, sex, race/ethnicity, education level and marital status were used as categorical control variables, and years in service as a continuous control variable, to reduce confounding. Additionally, tobacco use was dichotomised and controlled for in analyses since tobacco may be used as a weight management technique.

Mediator

Weight management behaviours. The measures of weight management behaviours used in this study are derived from the validated MEBS that provides a comprehensive, standardised, holistic and valid tool to examine eating habits mediators of eating behaviour in US military personnel[28]. Weight management behaviours were captured by the question 'Did you use any of the following methods leading up to your last Height & Weight/Tape test?' with options including 'Diet: changed what I ate, cut calories, skipped meals, eliminated a food group, or drank more water', 'Added new physical activity, increased time or intensity of usual exercise', 'Used muscle building, fat burning, or weight loss supplements', 'Neck exercises or wore a waist trainer to improve body fat measurements', 'Took diuretics, took laxatives (including Mg), or made myself vomit', 'Sat in a sauna/steam room, sat in Epsom salt bath, covered my body with Preparation H® and Saran Wrap, or stopped drinking water', and 'Other' which had an option to write in a response.

Statistical analysis

Data were analysed using Stata, v.15.1 (StataCorp) or SPSS, v.26 (IMB Statistics). Data were complete for all but three Soldiers (0·01 %) who had a missing response on race/ethnicity and one Soldier (0·002 %) who had a missing response on years of service. The data were screened for violations of assumptions prior to analysis. BMI and HEI score skewness and kurtosis were 0·35 and 2·94 and −0·11 and 2·97, respectively, but to aid interpretation, both were used without transformation[18]. No other violations were noted. The characteristics of Soldiers by frequency of self-reported weight cycling were examined using χ^2 and ANOVA statistics with *post hoc* tests to show between group differences. Additionally, we examined the characteristics of Soldiers based on those who did or did not complete the FFQ for between group differences.

For this cross-sectional study, multiple linear regression using the Stata *sem* command with full-information maximum likelihood estimation using the *mlvm* option was implemented to examine associations between weight cycling (dichotomous variable), weight management behaviours (categorical variable), and BMI or HEI scores (continuous variables). This estimation method assumes missing data among independent variables is missing at random, which allows the use of data from all participants who do not have missing data on the dependent variable. Root mean square error of approximation was used to assess goodness of fit.

Based on Hayes[34], simple associations between BMI, HEI score, weight cycling and weight management methods are not required as a pre-condition for pursuing a mediation analysis. Therefore, regardless of the presence or absence of simper associations, simple mediation models as described by Hayes[34] were implemented using the *process* command in SPSS to test the relationship between weight cycling and BMI, also known as the direct effect, and examine if weight management behaviours acts as a mediator between weight cycling and BMI, also known as the indirect effect. Using the same method, an additional model was implemented to test the same mediator relationship with the outcome of HEI score. The *process* command assumes complete data and excludes participants that have missing data on any of the variables included in the models. For mediation models, weight management behaviours were consolidated to create a categorical variable because the *process* command does not allow binary mediators. To ensure the normality of the sampling distribution and to assess the indirect effect of weight cycling on BMI and HEI score, through weight management behaviours, bootstrap CI were generated based on 10 000 bootstrap samples. Weight management behaviours were considered to be a mediator if the bootstrap 95 % CI for the indirect effect was above 0. All statistical models included several control variables which were selected a priori. Control variables included years of military service, sex, race/ethnicity, highest level of education achieved, military rank and marital status. Additionally, tobacco use was included as a control in all models since tobacco may be used for weight management purposes.

Results

Overall, 33 % of Soldiers reported weight fluctuations that met the criteria for weight cycling. BMI was higher (+1·8 kg/m^2, P < 0·001), but HEI score did not differ between Soldiers who reported weight cycling relative to those who did not (P = 0·46; Table 1). Soldiers who reported weight cycling were also more likely to engage in one or more weight management behaviours prior to body weight screening and had more years of service in the Army relative to those who did not report weight cycling (Table 1). For differences based on FFQ completion, no differences were observed on key variables of interest such as weight cycling or weight management methods; however, there were differences in age, years in service, education and marital status which were controlled for in statistical models and are likely due to heterogeneity at Army posts where the volunteers were recruited (online Supplementary Table 1).

In regression models, weight cycling was associated with a 1·09 point higher BMI which equated to 5·45 pounds (P < 0·001), using dieting with a 1·67 points higher BMI or 8·35 pounds (P =< 0·001), exercise with a 1·0 point higher BMI or 5·0 pounds (P = 0·007), and dehydration methods with a 1·46 point higher BMI or 7·3 pounds (P = 0·003), respectively (Table 2). Use of muscle building, fat burning or weight loss supplements prior to body weight screening was associated with

Table 1. Characteristics of soldiers, stratified by self-reported weight cycling (Percentages; mean values and standard deviations)

	Self-reported weight cycling									
	All (*n* 575)			Yes (*n* 190)			No (*n* 385)			
Socio-demographic variables, mean (SD) or %	%	Mean	SD	%	Mean	SD	%	Mean	SD	*P*
BMI (kg/m^2)		25·7	3·6		26·9	3·8		25·1	3·3	**< 0·001**
Underweight/normal: ≤ 24·9	44·9			30·5			52·0			**< 0·001**
Overweight: 25·0–29·9	43·8			51·6			40·0			**0·008**
Obese: ≥ 30·0	11·3			17·9			8·0			**< 0·001**
HEI-2015 total score		59·0	10·5		59·1	10·3		58·7	10·8	0·46
Weight management methods (%)										
Dieted	26·1				36·3		21·0			**< 0·001**
Increased exercise	30·3				38·4		26·2			**0·004**
Supplement use	13·0				17·9		10·6			**0·02**
Neck exercises/waist trainer	7·7				12·2		5·5			**0·01**
Diuretics/laxatives/vomiting	4·7				8·9		2·6			**0·001**
Dehydration (sauna/steam room)	11·3				18·4		7·8			**< 0·001**
Other methods	0·2				0·0		0·3			1·00
Sex										0·87
Male	89·6				90·0		89·4			
Female	10·4				10·0		10·6			
Age, years		23·4	4·4		23	4·3		23	4·5	0·14
Years of service in the army		2·3	2·8		3·0	3·3		2·0	2·5	**0·0001**
Race/ethnicity										
Non-Hispanic White	51·2			47·1			53·3			0·18
Non-Hispanic Black	14·7			17·5			13·3			0·21
Non-Hispanic Other	11·4			24·9			21·7			0·40
Hispanic	22·7			10·6			11·7			0·78
Education level										
High school/GED	53·0			49·5			54·8			0·25
Some college	32·0			34·2			30·9			0·45
Degree	15·0			16·3			14·3			0·54
Marital status										0·59
Single	61·0			59·5			61·8			
Married/living with a partner	30·0			40·5			38·2			
Use tobacco products	29·4			29·0			29·6			0·87
Rank categories										0·89
Enlisted	88·8			89·4			88·5			
Officer	11·2			10·6			11·5			

GED, General Educational Development Test; HEI, Healthy Eating Index.
Numbers in bold indicate differences significant at the P < 0·05 level.

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Table 2. Results of regression models of BMI or Healthy Eating Index (HEI) score by weight cycling and weight management methods (Coefficient values and standard errors)

	BMI (kg/m²) (*n* 575)			HEI score (*n* 441)*		
Predictor/mediator	*β*	SE	*P*	*β*	SE	*P*
Weight cycling	1·09	0·28	**< 0·001**	–0·35	1·05	0·74
Dieted	1·67	0·40	**< 0·001**	0·72	1·60	0·65
Increased exercise	1·00	0·39	**0·01**	1·19	1·53	0·44
Supplement use	–0·84	0·45	0·06	1·99	1·76	0·26
Neck exercises/waist trainer	1·05	0·58	0·07	–1·82	2·29	0·43
Diuretics/laxatives/vomiting	0·94	0·68	0·17	–2·21	2·66	0·41
Dehydration (sauna/steam room)	1·46	0·49	**0·003**	3·76	1·84	**0·04**
Other methods	1·21	3·11	0·70	8·69	10·47	0·41
Control variables						
Women	–2·70	0·44	**< 0·001**	0·92	1·73	0·60
Years of service	0·08	0·05	0·08	0·23	0·24	0·13
Non-Hispanic Black	–0·31	0·38	0·42	0·76	1·43	0·28
Non-Hispanic Other	0·22	0·42	0·60	–2·43	1·59	0·18
Hispanic	0·24	0·33	0·47	1·36	1·25	0·28
Some college	0·54	0·29	0·07	1·52	1·14	0·18
Degree	0·80	0·39	**0·04**	3·92	1·44	**0·01**
Married	0·57	0·28	**0·04**	–0·07	1·08	0·95
Used tobacco products	–0·01	0·29	0·98	–2·40	1·10	**0·03**
Constant	21·52	6·25	0·001	39·81	20·97	0·06

β, unstandardized regression coefficient. Weight cycling refers to ≥ 3 weight fluctuations of ±5 % of body weight. Referent group was no weight cycling, men, non-Hispanic White, high school education, single, no tobacco. Numbers in bold indicate level of significance at $P < 0·05$.
* Model included the 441 Soldiers who had HEI scores. Root mean square error of approximation for both models was 0·01.

lower BMI of 0·84 points or 4·2 pounds ($P = 0·02$). Using dehydration methods prior to body weight screening was associated with 3·76 higher HEI score ($P = 0·04$), which is of low practical significance.

The simple mediation models showed that weight cycling indirectly influenced both outcomes of BMI and HEI scores through its effect on weight management behaviours (Fig. 1). Thus, weight management behaviours mediated the relationship between weight cycling and BMI and weight cycling and HEI scores (Fig. 1). For the BMI model, both the direct and indirect effects were statistically significant demonstrating that weight cycling may affect BMI directly and through weight management behaviours as a mediator. In the model of HEI scores, there was no evidence that weight cycling influenced HEI scores independently of its effect on weight management behaviours showing that its effect on HEI scores was mediational only.

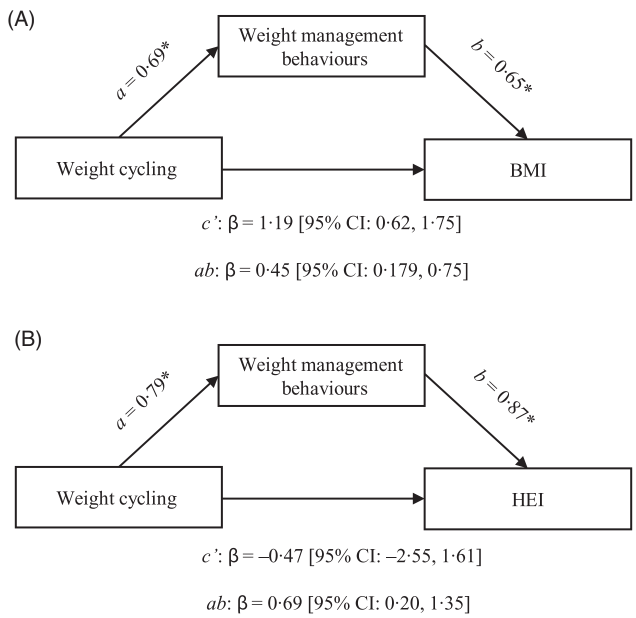

Figure 1. Mediation effect of weight management behaviors on the association between self-reported weight cycling and (A) BMI (*n* 571), and (B) Healthy Eating Index (HEI; *n* 441) score among Soldiers. Models adjusted for sex, years of service, race/ethnicity, education level, marital status and tobacco use. 95 % CI were generated from 10,000 bootstrap samples. Weight management behaviours were considered to be a mediator if the bootstrap 95% CI for the indirect effect was above zero. *ab*, indirect effect; *c*, direct effect. $^*P \leq 0.001$.

Discussion

This study examined the relationships between self-reported weight cycling, weight management behaviours prior to body weight screening, BMI and diet quality among US Army Soldiers. Findings indicate that weight cycling is common among US Army Soldiers and is associated with higher BMI and greater likelihood of adopting weight management behaviours prior to body weight screening. When examined further, adopting any weight management behaviour prior to body weight screening mediated associations between weight cycling and BMI and weight cycling and HEI scores. To our knowledge, these findings are the first to link weight management behaviours to weight cycling, BMI and diet quality in US Army Soldiers and suggest that weight management behaviours could be potentially modifiable intervention targets for Soldiers who weight cycle.

The 33 % prevalence of weight cycling observed in this study suggests that weight cycling is common in US Army Soldiers. In comparison, reports on weight cycling in civilian populations indicate a prevalence of 18 %–34 % in men and 20 %–55 % in women[35–39]. Prevalence of weight cycling in athletes is unclear, but previous studies estimated that around 50 % of athletes participating in combat sports (e.g. boxing, wrestling, mixed martial arts, judo, jiu-jitsu, karate, taekwondo), use rapid weight loss methods prior to competition[40,41]. Though studies differ in their definitions of weight cycling, the predominantly male population in the present study suggests that weight cycling in Soldiers may be as prevalent as that observed in civilian populations.

Soldiers who reported weight cycling were more likely to report higher BMI and adopting various weight management behaviours prior to body weight screening. Though causality cannot be demonstrated with these data, the association between weight cycling and BMI is consistent with robust data from civilian populations linking weight cycling with weight gain and higher BMI[2,6–10,42]. Notably, the observed association between weight cycling and BMI was independent of years of service in the Army. This may suggest that factors other than exposure to the Army environment, such as physiologic adaptations to weight loss that promote weight regain[4–6], may contribute to the relationship. Aspects of Army culture related to body composition standards may exacerbate the weight cycling relationship identified due to the stigma of being enrolled in a weight loss programme and potential impact on career progression. Previous studies have also demonstrated that military service members cyclically engage in weight management behaviours to comply with biannual physical fitness and body weight/composition screenings[10,12,43–45]. Those behaviours include purging or using diet pills, body wraps and saunas, and have been associated with body weight dissatisfaction and poor mental health outcomes[10,12,14,46]. Similarly, athletes participating in combat sports report behaviours such as increasing physical activity, using saunas and using plastic clothing to achieve rapid weight loss prior to competition[40]. Taken together, these findings suggest that pressure to meet the Army's body composition standards may be one factor which promotes the adoption of weight management behaviours in some Soldiers. Those behaviours, in turn, may contribute to higher BMI which would increase difficulty in complying with body weight and composition standards, thereby perpetuating cycles of losing and regaining weight.

Whether high BMI or an initial weight loss initiated weight cycling in the study population cannot be determined. However, regardless of the initiating factor, the cycle is likely to persist without interventions that prevent or modify the weight management behaviours mediating the association between weight cycling and BMI. In regression models, weight cycling was associated with a 1·09 point higher BMI which equated to 5·45 pounds ($P < 0·001$). Given that a Soldier's career can hinge on relatively small differences in body weight, these differences in BMI are occupationally meaningful. Potential interventions might include holistic initiatives that promote sustainable weight loss and healthy weight maintenance. For example, exposure to an Army eating environment, which is often characterised by limited and high-cost nutrient dense items, abundance of fast foods or hyper palatable foods, time constraints, and stress[16,27,46,47] early in a Soldier's career may foster the development of undesirable eating behaviours, such as fast eating and eating irrespective of hunger and fullness cues[16,47]. This exposure may inadvertently set Soldiers on a trajectory by which they must adopt weight management behaviours to compensate for these habits. In support, military personnel from various ranks have acknowledged that environmental barriers not only hinder behaviour changes but make application of healthy nutrition behaviours seem unrealistic[26]. The current military eating environment and social norms also do not acknowledge the multitude of factors that impact eating behaviours beyond the individual, such as environment and psychosocial influences[26,48]. When environmental and psychosocial factors are included within Army health promotion programmes, greater change in behaviours has resulted[48]. Creating a culture of health, removing barriers, moving beyond nutrition education alone and taking a more holistic approach to influencing behaviour change in Soldiers may therefore increase the effectiveness and sustainability of weight management interventions and warrant consideration in future research as aiming to prevent unwanted weight gain and weight cycling.

Results of the present study suggest that interventions aimed at improving diet quality also warrant consideration. Contrary to our hypothesis, weight cyclers did not report worse diet quality than those who did not weight cycle. This could reflect the lack of variability and relatively low HEI scores within the study population, and that dieters often eat healthier foods during periods of weight loss[3]. Notably, HEI scores for both those who did and did not report weight cycling received an 'F' for how closely dietary intakes conformed to the 2015 Dietary Guidelines for Americans, with totals scores being 59·1(10·3) and 58·7(10·8), respectively. Poor diet quality among Soldiers is consistent with recent studies that have reported Soldier eating patterns do not provide optimal energy availability, adequate macronutrient distribution or sufficient micronutrients when compared with sports nutrition guidelines or Military Dietary Reference Intakes[21,26,49]. Soldiers with more optimal diet quality are more likely to have more desirable body composition, APFT scores and emotional fitness scores[19]. Thus, diet quality, body weight and composition, mental health and occupational performance appear to be closely linked among US Army Soldiers. Notably, mediation analysis suggested that weight cyclers who adopted weight management behaviours had higher diet quality. However, that population also reported higher BMI. Taken together, those findings reinforce the need for holistic interventions aimed at promoting not just optimal diet quality, but also sustainable eating habits that facilitate long-term healthy body weight maintenance.

Strengths of this study include the use of a survey tailored to military populations, and the inclusion of Soldiers with diverse occupations and from multiple military installations located in different areas of the USA. However, despite this demographic and geographic diversity, the study population was slightly overrepresented by lower-ranking Soldiers in comparison to the full Active Duty population[50]. For example, officers comprise about 19 % of the full Active Duty population, but only 11 % of the study population. Thus, while findings are likely generalisable to enlisted Soldiers, the generalisability to officers requires further investigation. Several additional study limitations should also be noted. Foremost, the cross-sectional design precludes determining cause and effect. Another limitation was that the *process* command used in the mediation analysis, while widely

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used and accepted for estimating direct and indirect effects in mediation models[51], did not allow us to distinguish which specific weight management behaviour(s) acted as a mediator between study outcomes. Additionally, although both the MEBS and FFQ are validated tools, responses could have been influenced by social desirability bias, recall bias or individual biases. Height and weight were also self-reported which may introduce misreporting or recall bias. However, previous studies indicate that Soldiers are accurately able to report height and weight[30]. Finally, there is no standard definition of weight cycling which complicated comparisons of the prevalence of weight cycling in this cohort with that reported in other populations.

Conclusion

This study demonstrated that self-reported weight cycling is associated with higher BMI, and higher prevalence of adopting weight management behaviours prior to body composition screening in active duty Soldiers. This study is the first to suggest that weight management behaviours mediate the relationship between weight cycling and BMI and weight cycling and HEI scores among US Army Soldiers. Though cause and effect cannot be established, these findings extend the evidence base suggesting a relationship between Army body weight and composition standards, though well intentioned, and the adoption of weight management behaviours by some Soldiers that, rather than promoting health, could ultimately compromise health and occupational performance. As discussed above, aspects of Army culture related to body composition standards may exacerbate the weight cycling relationship identified due to the stigma of being enrolled in a weight loss programme and potential impact on career progression. Utilising the Army's arsenal of resources of medical and specialty providers to proactively educate Soldiers on the undesirable long-term consequences of weight cycling and the importance of good diet quality in an environment that models healthy behaviours warrants investigation as one strategy to healthy weight management and ensuring a nutritionally fit force.

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Authors R. C. and J. K. designed the study and wrote the protocol with assistance from S. M., K. O. and A. D. J. J., J. A. and J. K. developed the research questions for this manuscript with input from R. C. J. J., J. K., S. M., K. O., A. D., and R. C. collected the data. J. J. conducted the statistical analysis with input from J. A. and J. K. J. A. wrote the first draft of the manuscript. All authors contributed to subsequent manuscript drafts and have approved the final version.

The authors declare no conflicts of interest

Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S000711452100338X

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