Déterminants physiologiques et comportementaux du poids corporel chez la femme

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Thèse présentée à la
Faculté des études supérieures et postdoctorales
dans le cadre du programme de doctorat en santé des populations
en vue de l'obtention du grade de Philosophiae Doctor (Ph.D.)

Programme de doctorat en santé des populations
Université d'Ottawa

RÉSUMÉ

D'importantes fluctuations du poids corporel peuvent être observées à différentes périodes de la vie d'une femme la rendant ainsi plus vulnérable à une augmentation du risque de développer de l'obésité et des problèmes de santé. Bien que les approches actuelles préconisées dans le traitement de l'obésité produisent des résultats à court terme, le maintien d'une perte de poids à long terme s'avère une tâche difficile pour une majorité de gens. Il apparaît donc important, du point de vue de la santé des populations, de mieux comprendre les facteurs physiologiques et comportementaux associés à la problématique du poids chez la femme. C'est dans cette optique que s'inscrivent les travaux de la présente thèse. Deux études ont été utilisées afin de répondre aux questions de recherche de cette thèse : 1) une étude transversale réalisée auprès de femmes préménopausées ayant eu du succès avec le maintien d'une perte de poids; 2) une étude longitudinale d'une durée de 5 ans réalisée chez des femmes en période de transition ménopausique. Dans un premier temps, nous avons cherché à mieux comprendre les déterminants physiologiques et comportementaux susceptibles de favoriser le maintien d'une perte de poids à long terme chez la femme préménopausée en comparant des femmes ayant eu du succès avec le maintien de leur perte de poids à des femmes n'ayant jamais eu de problème de poids. Les résultats de cette étude transversale ont montré que le maintien d'une perte de poids à long terme chez la femme semble être associé à un apport protéinique plus élevé, un contrôle volontaire alimentaire cognitif plus important ainsi qu'à une plus grande dépense énergétique associée à l'activité physique. Dans un deuxième temps, nous avons observé que la relation entre la fréquence des repas et la composition corporelle chez les femmes préménopausées peut être influencée par l'activité physique et la condition cardio-respiratoire. Dans un troisième temps, nous nous sommes intéressés aux changements pouvant survenir au niveau des déterminants physiologiques et comportementaux associés à l'équilibre énergétique pendant la transition

ménopausique. Les résultats de cette étude longitudinale suggèrent que la transition ménopausique est accompagnée d'une diminution de la dépense énergétique, principalement caractérisée par une diminution de la pratique d'activité physique, et de l'adoption d'un mode de vie plus sédentaire. Une diminution de l'apport alimentaire ainsi qu'une augmentation de l'appétit ont également été observées. Dans l'ensemble, nous avons démontré qu'une pratique d'activité physique régulière d'intensité modérée à élevée ainsi qu'un apport protéinique plus élevé contribueraient au maintien d'une perte de poids à long terme chez la femme et qu'un gain de poids pendant la transition ménopausique pourrait être atténué par une augmentation de la pratique d'activité physique, l'adoption d'un mode de vie actif et une diminution de l'apport alimentaire.

AVANT-PROPOS

La réalisation d'un doctorat est une longue aventure qui nous amène à vivre une montagne russe d'émotions. L'atteinte de cette ultime étape n'aurait pu être possible sans l'appui indéniable de nombreuses personnes que la vie a posé sur mon chemin.

J'aimerais tout d'abord remercier mon directeur, Dr Éric Doucet, pour la confiance qu'il a eue en moi, sa compréhension, sa patience, ses encouragements et ses nombreux conseils tant appréciés. Merci Éric de m'avoir soutenue pendant toutes ces années! Ce fut un plaisir et un privilège de mener ce projet à terme à tes côtés.

L'accomplissement de projets de recherche ne peut se faire sans le soutien et la collaboration de nombreuses personnes. Merci à tous les gens qui m'ont aidée de près ou de loin dans la réalisation de ces passionnants projets de recherche. Je tiens tout spécialement à remercier Mme Ann Beninato, infirmière à l'Unité de recherche sur le comportement et le métabolisme (URCM), pour sa grande disponibilité, son implication et sa grandeur d'âme. Elle est un vrai petit rayon de soleil! Merci Ann pour toutes ces belles années passées en ta compagnie! J'aimerais également remercier Mme Isabelle Laforest, coordonnatrice de l'URCM, pour son soutien et sa joie de vivre. Que de plaisir j'ai eu en ta compagnie Isabelle! Merci pour tout! Je tiens également à remercier les Fonds de la Recherche en Santé du Québec (FRSQ) pour le soutien financier qui m'a été offert au cours de mes études au doctorat.

Je ne pourrai passer sous silence la belle complicité que j'ai eu la chance de développer avec mes collègues et amies Isabelle Giguère et Marie-Ève Riou. Merci les filles pour votre écoute, votre support et surtout pour votre amitié. Merci pour tous les précieux moments que nous avons partagés et merci d'avoir égayé mes journées! Je vous adore! Merci d'être dans ma vie!

Mes plus grands remerciements vont à mes parents, Ginette et Roger, ainsi qu'à mon frère Pierre-Luc, qui ont toujours été présents pour m'appuyer, m'encourager à continuer et à ne pas lâcher et me supporter dans les moments plus difficiles. Vous avez su m'apprendre que même si la vie n'est pas toujours facile, il faut garder espoir, car rien n'arrive pour rien. Merci pour cette leçon de vie, vous aviez bien raison. C'est grâce à vous que je suis rendue là où j'en suis aujourd'hui. Pour tout ce support et cet amour, je vous dis tout simplement merci!

Finalement, un merci tout spécial aux deux hommes de ma vie. Sans votre présence et votre soutien, je n'aurais pas accompli tout ce travail. Vous avec été ma source de motivation et de bonheur au quotidien. Vous avez su me remonter le moral dans les moments plus difficiles et me donner la force de continuer. Merci pour votre patience et votre compréhension. Yves, merci d'être toujours là pour moi et de m'appuyer dans tout ce que je fais. Laurent, merci d'être un petit homme aussi extraordinaire et attachant qui donne beaucoup d'amour à sa maman. Vous êtes ce que la vie m'a apporté de plus beau. Je vous aime!

À ma famille

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LISTE DES ABBRÉVIATIONS

ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
AUC	Area under the curve
% BF	Percentage of body fat
BMRU	Behavioural and Metabolic Research Unit
CIHR	Canadian Institutes of Health Research
CNFS	Consortium National de Formation en Santé
DXA	Ostéodensitométrie à absorptiométrie bi-photonique (dual-energy X-ray absorptiometry)
ECMS	Enquête canadienne sur les mesures de la santé
EE	Energy expenditure
EF	Eating frequency
EI	Energy intake
EOSS	Edmonton obesity staging system
FFM	Fat-free mass
FM	Fat mass
FMP	Final menstrual period
FRSQ	Fonds de la recherche en santé du Québec
FSH	Hormone folliculo-stimulante (Follicule-stimulating hormone)
IMC (BMI)	Indice de masse corporelle (Body mass index)
IOTF	Groupe de travail international sur l'obésité (International Obesity Task Force)

METs	Metabolic equivalents
MONET	Montreal Ottawa New Emerging Team study
NWCR	National Weight Control Registry
OMS (WHO)	Organisation mondiale de la santé (World Health Organization)
PAEE	Physical activity energy expenditure
PAL	Physical activity level
PEE	Postprandial energy expenditure
PFC	Prospective food consumption
REE	Resting energy expenditure
RMR	Resting metabolic rate
SWAN	Study of Women's Health Across the Nation
TEE	Total energy expenditure
TEF	Thermic effect of food
TFEQ	Three-Factor Eating Questionnaire
VAS	Visual analogue scale
$VO_{2\ max/peak}$	Consommation maximale d'oxygène/de pointe
WiLMA	Weight-Loss Maintenance study

INTRODUCTION

Au cours du siècle dernier, des changements fondamentaux dans notre façon de vivre et de construire notre environnement sont survenus entraînant des répercussions sur l'augmentation de la prévalence de l'obésité et la santé des populations [1]. Selon la « théorie évolutionnaire de discordance », l'obésité résulte d'une disparité entre le style de vie moderne et le style de vie dans lequel les humains et leurs gènes ont évolué [2]. La croissance économique, la modernisation, et l'urbanisation sont à l'origine de l'environnement « obésogène » caractérisé par une très grande accessibilité à des aliments peu coûteux, hautement palatable, à haute densité énergétique, combinée à un style de vie requérant très peu d'efforts physiques, dans lequel nous vivons aujourd'hui [3]. Cet environnement favorise la surconsommation d'aliments et contribue à diminuer la dépense énergétique journalière contribuant ainsi à favoriser un bilan énergétique positif [4].

Plusieurs stratégies d'interventions sont actuellement proposées pour aider les gens à atteindre leurs objectifs de perte de poids [5]. La majorité d'entre elles repose sur une réduction de l'apport calorique en combinaison avec une augmentation de la pratique d'activité physique, de façon à rétablir l'équilibre énergétique [6]. Bien que les interventions actuelles de perte de poids produisent des résultats à court terme [7-8], le maintien à long terme du poids perdu ne s'observe que chez une minorité d'individus [9-10].

D'importantes fluctuations du poids corporel peuvent être observées à différentes périodes de la vie d'une femme la rendant ainsi plus vulnérable à une augmentation du risque de développer l'obésité et des problèmes de santé [11-12]. La transition ménopausique représente l'une de ces périodes propices au changement de poids corporel chez la femme [13]. Un gain de poids et des changements dans la composition corporelle sont des phénomènes fréquents durant la période de la transition ménopausique [14-19]. Les facteurs en cause sont multiples. La perte de la fonction ovarienne, le vieillissement et les habitudes de vie ne sont pas étrangers aux changements corporels des femmes à l'approche de la ménopause. Il a été observé que 30% des femmes entrent en ménopause avec un problème d'embonpoint [20]. La prévention du gain de poids devrait donc être reconnue comme un objectif important pour la santé des femmes avant la ménopause. De plus, les femmes qui amorcent la période de la transition ménopausique devraient être informées des stratégies comportementales qui pourraient les aider à assurer un meilleur contrôle de leur poids et de leur composition corporelle.

C'est au cœur d'une telle problématique que s'inscrivent les travaux réalisés dans le cadre de la présente thèse de doctorat, au cours de laquelle nous nous sommes intéressés à identifier les facteurs physiologiques et comportementaux de la problématique du poids chez la femme. Le Chapitre 1 consiste en une présentation de la problématique des travaux. Ce chapitre contient plus spécifiquement quatre sections. Tout d'abord, une description générale du problème de l'obésité est présentée. Par la suite, la problématique du maintien d'une perte de poids à long terme est abordée. Cette section traite également des déterminants et stratégies qui favorisent le succès du maintien d'une perte de poids à long terme. La troisième section expose la problématique du poids pendant la transition ménopausique et fait état des connaissances en ce qui concerne l'impact des facteurs physiologiques et comportementaux associés à l'équilibre énergétique sur le poids et la composition corporelle des femmes ménopausées. Enfin, ce chapitre se termine par une présentation de la contribution des travaux de recherche de la thèse au domaine de la santé des populations. Le Chapitre 2 porte quant à lui sur les aspects méthodologiques de la thèse. En fait, c'est dans ce chapitre qu'est présenté la pertinence des études réalisées, les objectifs et hypothèses ainsi qu'une description des projets de recherche de cette thèse.

De façon à mieux comprendre l'enjeu des déterminants physiologiques et comportementaux dans la problématique du poids chez la femme, différentes questions de recherche ont donc été abordées par le biais de deux études. Dans un premier temps, une étude conçue afin d'identifier les variables physiologiques et comportementales pouvant caractériser le maintien d'une perte de poids à long terme chez la femme a été réalisée [projet WiLMa (Weight-Loss Maintenance)]. Selon un devis transversal, une comparaison entre des femmes préménopausées ayant réussi à maintenir une perte de poids à long terme et des femmes préménopausées n'ayant jamais eu de problème de poids a été effectuée. Les résultats qui découlent de ces travaux constituent l'essentiel du premier manuscrit présenté dans cette thèse (Chapitre 3). Par la suite, dans le cadre du deuxième manuscrit (Chapitre 4), nous tenions à mesurer la relation entre la fréquence des repas et la composition corporelle chez la femme préménopausée. Pour ce faire, nous avons procédé à une analyse transversale des données obtenues dans le cadre d'une étude longitudinale sur la ménopause [projet MONET (Montreal Ottawa New Emerging Team)]. Finalement, nous nous sommes intéressés à l'effet de la transition ménopausique sur les déterminants associés à l'équilibre énergétique. Cet aspect a été investigué dans le cadre d'une des études MONET, plus particulièrement l'étude longitudinale d'une durée de 5 ans réalisée auprès de femmes préménopausées susceptibles de devenir post-ménopausées pendant la durée de l'étude. Une analyse longitudinale des variables physiologiques et comportementales associées à l'équilibre énergétique a été effectuée. Les troisième et quatrième manuscrits présentent les résultats qui proviennent de ces travaux (Chapitre 5 et 6). Quant au dernier chapitre de cette thèse (Chapitre 7), on y retrouve un résumé des résultats présentés dans les chapitres 3 à 6 ainsi que les implications et les perspectives des résultats découlant de la présente thèse. Cette thèse comprend également une annexe dans laquelle un chapitre de livre, que j'ai rédigé dans le cadre des mes études doctorales, portant sur la fréquence des repas et le poids corporel est présenté (Annexe A).

CHAPITRE 1

PROBLÉMATIQUE DES TRAVAUX

1.1 La problématique de l'obésité

Depuis l'apparition de l'homme, jusqu'à récemment, l'homme vivait une vie nomade et devait chasser, pêcher et faire la cueillette de fruits pour se nourrir [21]. La nourriture était une denrée rare et mener une vie active était essentiel pour assurer sa survie. Le stockage d'énergie, entre autre sous forme de graisses, permettait de faire face aux famines qui étaient régulières et fréquentes. L'accumulation de tissu adipeux était donc une nécessité biologique [22]. Aujourd'hui, nous connaissons une modification de ce paradigme suite à des changements fondamentaux dans notre façon de vivre et de construire notre environnement [23]. Nous vivons dans un environnement « obésogène », caractérisé par une surabondance de nourriture et un mode de vie sédentaire, auquel notre organisme n'est pas adapté [24].

1.1.1 Obésité : définition et prévalence

L'obésité se définit comme un excès de poids, principalement causé par une augmentation de la masse adipeuse chez un individu [25]. L'obésité peut être évaluée à l'aide de deux indicateurs simples à mesurer en clinique : l'indice de masse corporelle (IMC) = poids (kg) / taille (m^2) et le tour de taille [5]. Bien que ces indicateurs n'évaluent pas directement l'adiposité, ils permettent d'avoir un aperçu de la masse totale d'un individu proportionnellement à sa grandeur de même que de la distribution du tissu adipeux. Le **tableau 1.1** présente les lignes directrices canadiennes pour la classification du poids et du risque pour la santé en fonction de l'IMC et du tour de taille. Le **tableau 1.2** présente quant à lui la classification du risque pour la santé en combinant l'IMC et le tour de taille. On peut observer que même si une personne a un poids normal, elle peut tout de même avoir un risque accru de développer des problèmes de santé si son tour de taille est élevé. Cela illustre la pertinence d'utiliser ces deux indicateurs de façon concomitante afin d'évaluer le risque pour la santé d'un individu.

Tableau 1.1. Lignes directrices canadiennes pour la classification du poids et du risque pour la santé chez les adultes en fonction de l'IMC et du tour de taille.

Classification du poids		IMC (kg/m^2)	Risque de développer des problèmes de santé
Poids insuffisant		**< 18,5**	**Risque accru**
Poids normal		**18,5 - 24,9**	**Moindre risque**
Excès de poids		**25,0 - 29,9**	**Risque accru**
Obésité	**Classe I**	**30,0 - 34,9**	**Risque élevé**
	Classe II	**35,0 - 39,9**	**Risque très élevé**
	Classe III	**≥ 40,0**	**Risque extrêmement élevé**
Classification du tour de taille			
Homme		**< 102 cm**	**Moindre risque**
		≥ 102 cm	**Risque accru**
Femme		**< 88 cm**	**Moindre risque**
		≥ 88 cm	**Risque accru**

Tableau adapté de : Douketis JD et al., 2005 [26].

Tableau 1.2. Classification du risque pour la santé en combinant les effets de l'IMC et du tour de taille.

		IMC		
		Normal 18,5-24,9 kg/m²	**Excès de poids 25-29,9 kg/m²**	**Obésité classe I 30-34,9 kg/m²**
Tour de taille	**< 102 cm (hommes) < 88 cm (femmes)**	Moindre risque	Risque accru	Risque élevé
	≥ 102 cm (hommes) ≥ 88 cm (femmes)	Risque accru	Risque élevé	Risque très élevé

Tableau adapté de : Douketis JD et al., 2005 [26].

Malgré les efforts et les ressources investis dans la prévention du gain de poids et le traitement de l'obésité au fil des dernières années, la prévalence d'excès de poids et de l'obésité n'a jamais été aussi élevée [27-31]. Selon les données de l'Enquête canadienne sur les mesures de la santé (ECMS) de 2007-2009 publiées par Statistique Canada, près d'un adulte canadien sur quatre souffre d'obésité (IMC $\geq$ 30 kg/m^2) [32]. Au cours des dernières décennies, le nombre de Canadiens présentant de l'embonpoint ou souffrant d'obésité s'est accru de manière considérable. En effet, le taux d'obésité à l'échelle canadienne aurait presque doublé entre 1978 et 2009 [33]. En 1978-1979, la prévalence de l'obésité se situait à 13,8% au Canada, alors qu'elle se chiffre aujourd'hui à 24,3% [32, 34]. La proportion de Canadiens présentant un surplus de poids a également augmentée au cours des dernières années, se situant à 37% en 2009 [32]. Globalement, ces statistiques indiquent que plus de la moitié des adultes canadiens, soit 61% de la population, présente un excès de poids (IMC ≥ 25 kg/m^2) [33].

1.1.2 Conséquences de l'obésité sur la santé

L'obésité est reconnue comme un facteur de risque important pour plusieurs maladies chroniques et problèmes de santé tels que les maladies cardiovasculaires, le diabète de type 2, une lipidémie anormale, l'apnée du sommeil et autres maladies respiratoires, l'ostéoarthrite, l'infertilité et certains types de cancer (dont le cancer du côlon, du sein, de la prostate et de l'endomètre) [1, 6, 35]. L'obésité peut s'avérer être également un fardeau sur les plans psychologique et social. En effet, la présence d'un surplus de poids peut entraîner des conséquences sur le bien-être des individus ainsi que sur leur qualité de vie se traduisant par un risque plus élevé de présenter une dépression, de l'anxiété, une faible estime de soi ainsi qu'un sentiment d'exclusion sociale et d'incompréhension [36-40]. Cependant, l'obésité est une condition hétérogène, tant dans son étiologie que ses complications, de sorte que ce ne sont pas tous les individus obèses qui développeront des complications associées à leur excès de poids. En effet, un groupe d'individus obèses métaboliquement en santé à été décrit dans la littérature médicale [41-45]. Malgré une adiposité excessive, ces individus présentent un profil cardiométabolique favorable caractérisé par des niveaux élevés de sensibilité à l'insuline, l'absence d'hypertension ainsi que des profils lipidique, inflammatoire, hormonal et immunitaire normaux [46-51].

L'hypothèse selon laquelle l'adiposité augmente le risque de mortalité n'est pas clairement supportée par les évidences scientifiques actuelles. En effet, la majorité des études épidémiologiques ont montré que les individus qui sont en surpoids ou modérément obèses vivent aussi longtemps et même plus que les individus de poids normal [52-54]. Une récente métaanalyse réalisée par Flegal et al. [55] indique une diminution du risque de mortalité chez les individus présentant un excès de poids (25 ≤ IMC < 30 kg/m²) comparativement à des individus de poids normal (18,5 ≤ IMC < 25 kg/m²). Bien qu'une augmentation du risque de mortalité a été notée chez les individus obèses (IMC ≥ 30 kg/m²), ce risque n'était significatif seulement dans les cas d'obésité plus sévères (IMC ≥ 35 kg/m²). Les individus modérément obèses (30 ≤ IMC < 35 kg/m²) ne présentaient pas d'augmentation significative du risque de mortalité comparativement aux individus de poids normal. Ces résultats suggèrent que l'utilisation seule de l'IMC comme prédicteur de la mortalité peut mener à des conclusions erronées. Une évaluation des comorbidités, du profil de risque pour la santé (tension artérielle, taux de lipides et de glucose sanguins,…) et des habitudes de vie de façon concomitante avec l'IMC et le tour de taille est donc recommandée dans l'évaluation du risque de mortalité des individus [6, 56]. Récemment, une nouvelle approche pour l'évaluation du risque de mortalité associé à l'obésité a été proposée : *« the Edmonton Obesity Staging System (EOSS) »* [57-58]. Cette approche permet de classer les individus présentant un excès de poids (IMC ≥ 25 kg/m²) en 5 catégories selon leurs comorbidités, leur statut fonctionnel et leur profil de risque pour la santé (**Tableau 1.3**) afin d'identifier ceux à risque plus élevé de mortalité et qui pourraient bénéficier de plus d'attention concernant le contrôle de leur poids corporel.

Tableau 1.3. Évaluation du risque de mortalité associé à l'obésité selon *« The Edmonton Obesity Staging System »*.

0	Aucun facteur de risque apparent (par exemple, pression artérielle, taux de lipides et niveau de glucose à jeun dans les valeurs normales), de symptômes physiques, de psychopathologie, de limitations fonctionnelles et/ou une altération du bien-être associés à l'obésité.
1	Présence de facteurs de risque sous-cliniques associés à l'obésité (par exemple, hypertension artérielle limite, intolérance au glucose, niveaux élevés d'enzymes hépatiques), symptômes physiques légers (par exemple, dyspnée à l'effort modérée, douleurs occasionnelles, fatigue), psychopathologie légère, limitations fonctionnelles légères et/ou une altération légère du bien-être.
2	Présence de maladies chroniques associées à l'obésité (par exemple, hypertension artérielle, diabète de type 2, apnée du sommeil, arthrose), limitations modérées dans les activités de la vie quotidienne et/ou une altération modérée du bien-être.
3	Dommages aux organes vitaux tels que : infarctus du myocarde, insuffisance cardiaque, accident vasculaire cérébral, psychopathologie significative, limitations fonctionnelles significatives et/ou une altération significative du bien-être.
4	Handicaps sévères engendrés par la présence de maladies chroniques associées à l'obésité (potentiellement en phase terminale), psychopathologie invalidante, limitations fonctionnelles sévères et/ou une altération sévère du bien-être.

Tableau adapté de : Padwal et al., 2011 [58].

1.1.3 Déterminants impliqués dans le développement de l'obésité

La cause fondamentale de l'obésité et du surpoids est un déséquilibre énergétique entre les calories consommées et celles dépensées [1]. Cependant, la simplicité de ce concept d'équilibre énergétique cache la nature complexe de l'influence de nombreux facteurs impliqués dans cette équation [59]. Lorsque nous tentons de comprendre pourquoi l'obésité est si répandue, nous constatons que les facteurs contributifs sont multiples [60]. Il s'agit non seulement de déterminants biologiques, mais également de déterminants environnementaux qui peuvent influencer les individus à adopter des comportements à risque tels qu'une consommation accrue de calories et/ou une diminution de l'activité physique conduisant généralement à un bilan énergétique positif [59, 61-62] (**Figure 1.1**).

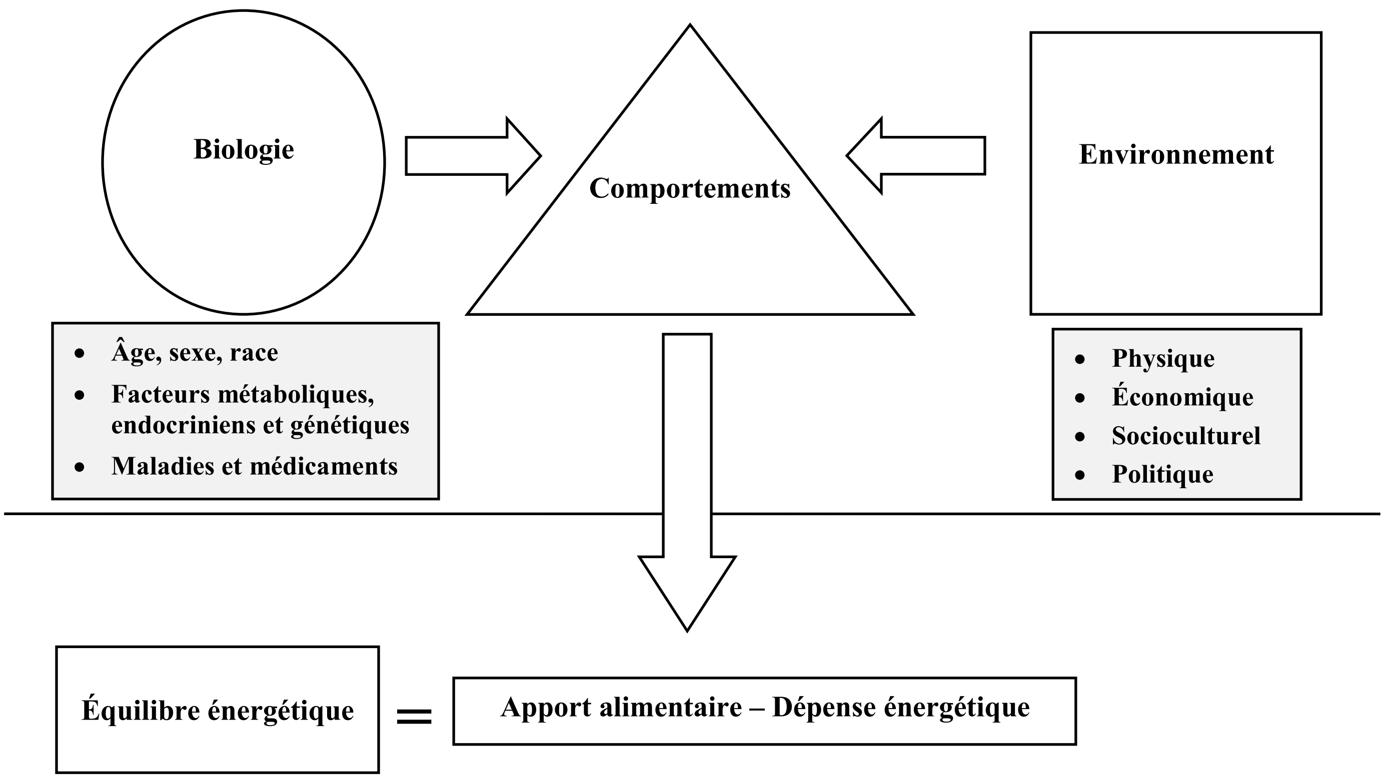

Figure 1.1. Modèle écologique présentant les facteurs contributifs à l'obésité ainsi que leurs interactions.

Figure adaptée de : Egger et al., 1997 [63] et Swinburn et al., 1999 [64].

Bien que la susceptibilité de devenir obèse soit en partie déterminée par des facteurs génétiques, il est indispensable d'avoir un environnement propice pour que ces gènes puissent s'exprimer [61].

La contribution simultanée de la biologie et de l'environnement aux problèmes de poids a été bien résumée par le Dr Bray, chercheur émérite dans le domaine de l'obésité : « (…) le bagage génétique charge le fusil, mais l'environnement appuie sur la gâchette » [65]. Plusieurs recherches ont montré l'influence de la génétique dans la prédisposition des individus à l'obésité, mais celle-ci ne peut, à elle seule, sauf dans de rares cas, en expliquer l'épidémie [66]. Lorsqu'on considère que le génotype d'une espèce s'adapte que sur une très longue période, il est peu probable que nos gènes aient changé au cours du siècle dernier expliquant ainsi la poussée fulgurante de l'obésité [2, 67]. Toutefois, des modifications épigénétiques qui seraient apparues chez nos ancêtres et auraient été transmises aux générations actuelles pourraient jouer un rôle dans l'augmentation de la prévalence d'obésité [68]. Selon l'Organisation mondiale de la santé (OMS), l'augmentation du poids des populations que nous connaissons actuellement semble être plutôt attribuable aux profonds changements survenus dans notre société au cours des dernières décennies se traduisant par un environnement « obésogène » où la nourriture riche en énergie est abondante et accessible et où les efforts physiques sont réduits au minimum [25, 62]. En effet, nos activités quotidiennes requièrent de moins en moins d'énergie [3]; nos loisirs et nos moyens de transport sont de plus en plus sédentaires [3, 66]; notre alimentation est souvent riche en lipides et à haute densité énergétique [3]; les portions sont de plus en plus généreuses, ce qui favorise la surconsommation [69]; les aliments sont disponibles en tout temps et les aliments dense en énergie sont souvent moins dispendieux [3]. Les habitudes alimentaires et la pratique d'activité physique représentent donc des déterminants clés dans le contrôle du poids corporel et ces derniers sont grandement influencés par l'environnement dans lequel nous vivons [70].

1.1.4 Déterminants physiologiques et comportementaux associés à un bilan énergétique positif

Les deux prochaines sections ont pour objectif de présenter un survol du contrôle de la prise alimentaire ainsi que des déterminants associés à la dépense énergétique.

1.1.4.1 Apport énergétique

L'apport énergétique total représente l'ensemble de l'énergie consommée sous forme d'aliments et de boissons pouvant être métabolisés par l'organisme [25]. L'appétit, certains comportements alimentaires, la fréquence des repas et la composition en macronutriments (lipides, glucides, protéines) des aliments représentent quatre facteurs pouvant influencer l'apport énergétique et ainsi avoir un impact sur le poids corporel [25]. L'appétit est constitué de sensations (envie de manger, sensation de faim, sensation de satiété, quantité de nourriture pouvant être ingérée) qui favorisent ou qui inhibent l'ingestion d'aliments [71]. Il a été observé qu'une envie de manger et une sensation de faim élevées étaient associées à une perte de poids plus faible [72]. De plus, certains comportements reliés à l'alimentation peuvent également avoir une influence sur l'apport alimentaire [73-75]. Même s'il serait logique de croire qu'une plus grande restriction alimentaire chez un individu devrait être associée à un poids plus faible, une telle affirmation est loin de faire l'unanimité dans la littérature. En effet, plusieurs études ont rapporté des associations positives entre la restriction alimentaire et l'IMC [76-77], alors que d'autres n'ont trouvé aucune relation [78-81] ou des relations inverses [82]. Quant aux comportements de désinhibition et la susceptibilité à la faim, ils ont été associés positivement avec le gain de poids [80-81, 83-86]. En ce qui concerne la fréquence des repas, bien que plusieurs études n'aient observé aucune relation entre la fréquence des repas et la composition corporelle [87-91], les résultats demeurent controversés [92-95]. Enfin, il a été observé qu'une alimentation à faible densité énergétique (faible en lipides et riche en fibres et en protéines) peut favoriser une augmentation de la satiété et ainsi contribuer à diminuer l'apport calorique [96].

1.1.4.2 Dépense énergétique

La dépense énergétique totale représente la somme du métabolisme de repos, de l'effet thermique des aliments et de l'énergie dépensée au cours de l'activité physique [97]. Le métabolisme de repos, composante principale de la dépense énergétique, représente la quantité minimale d'énergie dont l'organisme a besoin pour survivre [98]. Il représente environ 60% de la dépense énergétique totale chez un individu sédentaire [98]. L'effet thermique des aliments correspond au coût énergétique de l'absorption, du stockage et de la digestion des aliments et représente environ 10% de la dépense énergétique totale [98]. Enfin, l'énergie dépensée par la pratique d'activité physique représente environ 30% de la dépense énergétique totale [98]. Toute diminution importante de la dépense énergétique pouvant contribuer à l'augmentation de la prévalence de l'obésité est attribuée à une diminution de l'activité physique, le facteur modifiable le plus important de la dépense énergétique [98]. Selon l'Enquête canadienne sur les mesures de la santé (ECMS) de 2007-2009, seulement 14% des femmes âgées de 20 à 79 ans atteignent les recommandations canadiennes en matière d'activité physique consistant à cumuler au moins 150 minutes d'activité physique modérée à vigoureuse par semaine [99]. De plus, 69% des femmes canadiennes consacrent la majorité de leurs heures de veilles, soit 10h par jour en moyenne, à des activités sédentaires (écouter la télévision, conduire, lire, être assis, être allongé, être debout,…) caractérisées par une faible dépense énergétique $\leq$ 1,5 METs [99]. Enfin, à peine le quart des femmes (25,4%) cumulent en moyenne 10 000 pas par jour [99], nombre de pas associé à un mode de vie actif dans la population générale [100]. Des données transversales révèlent un rapport inverse entre l'IMC et le niveau d'activité physique, indiquant que les individus présentant un surplus de poids ou souffrant d'obésité sont souvent moins physiquement actifs que les individus de poids normal [99, 101-103].

Bien que les conséquences de l'obésité sur la santé des populations soient importantes et reconnues par les organisations internationales de santé incluant Santé Canada, les Instituts Nationaux de la Santé et l'OMS, le résultat des efforts pour prévenir et traiter l'obésité sont extrêmement décevants. Le problème réside dans le fait que peu de personnes réussissent à maintenir leur perte de poids à long terme [9].

1.2 Le maintien d'une perte de poids à long terme

Plusieurs stratégies d'interventions sont proposées pour aider les gens à atteindre leurs objectifs de perte de poids [5]. Celles-ci peuvent prendre diverses formes telles que l'adoption de saines habitudes alimentaires, une pratique régulière d'activité physique, une thérapie cognitivocomportementale, la pharmacothérapie et la chirurgie bariatrique. Bien que l'ensemble des interventions actuelles de perte de poids produisent des résultats à court terme, le maintien à long terme du poids perdu ne s'observe que chez une minorité d'individus [9-10, 104]. En effet, le maintien d'une perte de poids à long terme s'avère une tâche difficile pour une majorité de gens qui s'efforcent de suivre les approches traditionnelles préconisées dans le traitement de l'obésité [9]. Des recherches ont montré qu'environ 20% des individus présentant un surplus de poids ou souffrant d'obésité réussissent à perdre et maintenir au moins 10% de leur poids initial à long terme [105-107]. De plus, la plupart des personnes suivant un régime amaigrissant regagnent environ ⅓ du poids perdu pendant l'année suivant la perte de poids et reviennent généralement à leur poids de départ dans les 3 à 5 ans suite à l'intervention [108].

1.2.1 Difficultés associées au maintien d'une perte de poids à long terme

Cette difficulté à maintenir une perte de poids peut s'expliquer, en partie, par des altérations physiologiques pouvant survenir suite à une perte de poids rapide et importante (> 10%) ainsi qu'à plusieurs cycles de perte et regain de poids [109-113]. Les régimes amaigrissants, surtout ceux préconisant un déficit calorique sévère et à répétition, entraînent des variations importantes du poids corporel. De tels régimes alimentaires ont pour conséquence de diminuer le métabolisme de repos et de réduire le taux de leptine, une hormone sécrétée par le tissu adipeux qui affecte la dépense énergétique et l'appétit, ce qui peut occasionner une augmentation de l'appétit se traduisant par une augmentation de la sensation de faim et du risque de fringales [112-115]. De plus, une augmentation du système de récompense se traduisant par une augmentation de la palatabilité et de l'olfaction, suite à une restriction calorique, a été récemment observée [116-117]. Par conséquent, la probabilité de regagner le poids perdu augmente considérablement nuisant ainsi au contrôle du poids à long terme. Une autre des raisons pouvant expliquer le faible taux de succès dans le maintien d'une perte de poids pourrait être que les stratégies favorisant une perte de poids diffèrent de celles nécessaires pour assurer le maintien du poids perdu. Dans une enquête transversale menée auprès de 1165 adultes américains qui ont perdu > 30 lb et qui ont maintenu cette perte de poids pendant une période minimale de 12 mois, Sciamanna et al. [118] ont documenté, à l'aide d'un questionnaire, les stratégies utilisées pour perdre du poids ainsi que celles pour maintenir le poids perdu. Parmi les 36 stratégies identifiées, seulement 8 d'entre elles ont été associées à la fois à la perte et au maintien de poids : 1) manger beaucoup de fruits et légumes; 2) diminuer les portions de glucides; 3) diminuer la grosseur des portions; 4) planifier la liste des aliments à acheter avant de se rendre à l'épicerie; 5) lire les étiquettes nutritionnelles; 6) penser au progrès qui a été fait; 7) penser aux objectifs de perte de poids; et 8) se peser régulièrement. Les résultats de cette étude montrent que le maintien d'une perte de poids peut nécessiter un plan d'intervention différent de celui utilisé pour la perte de poids. Une des raisons évoquée pour expliquer cette différence est la motivation qui est souvent très élevée en début de programme de perte de poids et qui peut diminuer avec le temps nécessitant ainsi différentes stratégies afin d'assurer un contrôle adéquat du poids corporel à long terme telles que : 1) se récompenser pour avoir réussi à suivre son plan alimentaire et d'activité physique; et 2) se rappeler pourquoi il est important de contrôler son poids. Considérant les résultats passagers qui découlent des stratégies d'interventions actuelles recommandées dans la prise en charge de l'obésité, une meilleure connaissance des facteurs associés au maintien du poids à long terme est souhaitable.

1.2.2 Définition du succès du maintien d'une perte de poids

Bien qu'il n'existe toujours pas de définition précise quant au succès à long terme d'une démarche de perte de poids [119], il a été suggéré qu'une perte de poids volontaire de 5 à 10 % du poids initial, maintenue pendant au moins un an, pourrait être considérée comme une réussite [120-121]. Cette définition est supportée par le fait qu'il a été observé qu'une perte de poids modérée et maintenue de l'ordre de 5 à 10 % du poids initial est suffisante pour bénéficier de bienfaits importants pour la santé tels que la prévention et l'amélioration des facteurs de risque des maladies cardiovasculaires et du diabète [6].

1.2.3 Déterminants du succès du maintien d'une perte de poids

Des études antérieures ont permis d'identifier certains comportements et stratégies associés au maintien d'une perte de poids à long terme. Une grande partie de ces connaissances ont été obtenue avec l'aide du *« National Weight Control Registry (NWCR) »* qui a été créé en 1994 aux États-Unis dans le but de documenter les facteurs caractérisant les individus qui réussissent à maintenir une perte de poids à long terme [122]. Le *NWCR* constitue l'étude prospective la plus importante concernant le maintien d'une perte de poids à long terme [121-122]. Ce registre contient actuellement des renseignements sur plus de 5000 adultes ayant réussi à perdre au moins 13,6 kg (30 lb) et à le maintenir pendant plus d'un an [122]. Les analyses effectuées avec les données de ce registre ont permis d'identifier des facteurs associées au maintien d'une perte de poids à long terme. Sommairement, les résultats de ces analyses indiquent que les comportements et stratégies communes aux individus qui réussissent à maintenir une perte de poids à long terme sont : 1) faire de l'activité physique de façon régulière à raison d'au moins une heure par jour à intensité modérée à élevée, équivalent à de la marche rapide [123-125]; 2) avoir une alimentation faible en énergie et en lipides, représentant environ 1400 kcal par jour dont moins de 24% provenant des lipides [126]; 3) surveiller régulièrement son poids (44% des membres du registre ont déclaré se peser au moins une fois par jour et 31% au moins une fois par semaine) [127]; 4) consommer quotidiennement un petit déjeuner [128]; 5) avoir une alimentation saine et constante tout au long de la semaine (les individus qui avaient maintenu une alimentation saine, autant la semaine que la fin de semaine, étaient 1,5 fois plus susceptibles de maintenir leur poids (± 5 lb) que ceux qui rapportaient avoir une diète plus stricte les jours de semaine) [129]; 6) manger environ 5 fois par jour [122]; 7) avoir une plus grande restriction alimentaire [130]; 8) passer un minimum de temps à regarder la télévision (62% des membres du registre ont déclaré regarder 10 heures ou moins de télévision par semaine) [131]; et 9) prendre en charge rapidement le regain de poids avant qu'il ne devienne trop important [132].

D'autres facteurs ont également été associés à un meilleur maintien de poids à long terme tels qu'un métabolisme de repos plus élevée [10], une diminution de la grosseur des portions des aliments consommés et une réduction de la fréquence des collations [121]. Pasman et al. [133] ont observé que les individus ayant fait plusieurs régimes alimentaires au cours de leur vie ont tendance à regagner davantage de poids que ceux qui ont fait moins de tentatives de perte de poids (8,8 ± -1,0 vs. 5,1 ± 0,8 kg, $P < 0,01$). Certains comportements alimentaires joueraient également un rôle dans le succès du maintien d'une perte de poids à long terme. En effet, un faible niveau de désinhibition a été associé à un meilleur maintien d'une perte de poids à long terme [132, 134]. La désinhibition consiste en la consommation excessive d'aliments en réponse à certains stimuli externes, comme le stress émotionnel. Wing et al. [132] ont observé que les individus qui avaient un comportement de désinhibition plus faible [« score » < 6 sur le *Three-Factor Eating Questionnaire (TFEQ)*] avaient 60% plus de chance de maintenir leur poids pendant plus d'un an. Le fait de présenter une restriction alimentaire plus élevée ainsi qu'un comportement de susceptibilité à la faim plus faible ont également été associés à un maintien de poids à long terme [10, 86, 134]. La restriction alimentaire consiste en un contrôle conscient de la consommation d'aliments afin de surveiller son poids corporel tandis que la susceptibilité à la faim consiste en la consommation d'aliments en présence de déclencheurs qui stimulent la faim ou l'impression d'avoir faim. Le **Tableau 1.4** présente un résumé des facteurs pouvant être associés au maintien d'une perte de poids ainsi qu'au regain de poids.

Tableau 1.4. Facteurs associés au maintien d'une perte de poids ainsi qu'au regain de poids.

Maintien d'une perte de poids	Regain de poids
Atteinte de l'objectif de perte de poids	Attribuer l'obésité à des facteurs médicaux
Plus grande perte de poids en début de traitement	Percevoir des barrières à la perte de poids
Vie active	Histoire de fluctuation de poids
Rythme de repas régulier	Vie sédentaire
Prise quotidienne d'un déjeuner	Comportement de désinhibition
Alimentation contenant moins de lipides et plus d'aliments sains	Susceptibilité à la faim plus grande
Diminution du nombre de collations	Hyperphagie boulimique
Comportement de restriction alimentaire flexible	Manger en réponse à des émotions négatives et au stress
Auto-surveillance	Facteurs de stress psychosocial
Capacité d'adaptation	Manque de soutien social
Capacité à gérer les fringales	Réactions passives à des problèmes
Auto-efficacité	Mauvaises stratégies d'adaptation
Autonomie	Manque de confiance en soi
Narcissisme sain	Psychopathologie
Motivation à perdre du poids = avoir plus de confiance	Motivation à perdre du poids = raisons médicales, pour d'autres personnes
Vie stable	Pensée dichotomique (tout-ou-rien)
Soutien social	

Tableau adapté de : Elfhag et Rössner, 2005 [86].

Une étude récente réalisée par Ogden et al.[135] à partir des données du NWCR a permis d'identifier quatre groupes d'individus distincts ayant réussi à maintenir une perte de poids à long terme, où chacun partagent des caractéristiques communes :

1) Individu en poids stable, en santé, conscient de l'importance de l'activité physique et satisfait avec son poids actuel (représente 50,5% des participants);

2) Individu qui lutte continuellement pour contrôler son poids depuis l'enfance, compte sur le plus grand nombre de ressources et de stratégies pour perdre et maintenir son poids et rapporte des niveaux élevés de stress et de dépression (représente 26,9% des participants);
3) Individu qui a eu du succès avec sa perte de poids lors de la première tentative, moins susceptible d'avoir été en excès de poids lorsqu'il était enfant et maintien sa perte de poids depuis la plus longue période de temps (représente 12,7% des participants);
4) Individu moins susceptible de faire de l'activité physique pour contrôler son poids, tendance à être plus âgé, à manger moins de repas et rapporte plus de problèmes de santé.

Ces résultats montrent qu'il est possible pour différents individus de maintenir une perte de poids à long terme et que les stratégies utilisées doivent être adaptées aux caractéristiques spécifiques de chaque individu. Cette étude reflète l'hétérogénéité et la grande variabilité individuelle du contrôle du poids corporel ainsi que l'interaction complexe de divers facteurs psychologiques, sociaux et biologiques.

1.3 La transition ménopausique, une période propice au changement de poids et/ou de composition corporelle chez la femme

La prévalence de l'obésité chez la femme augmente avec l'âge et atteint un niveau maximal entre 45 et 64 ans, période de la vie d'une femme généralement associée à la transition vers la ménopause (**Figure 1.2**) [34].

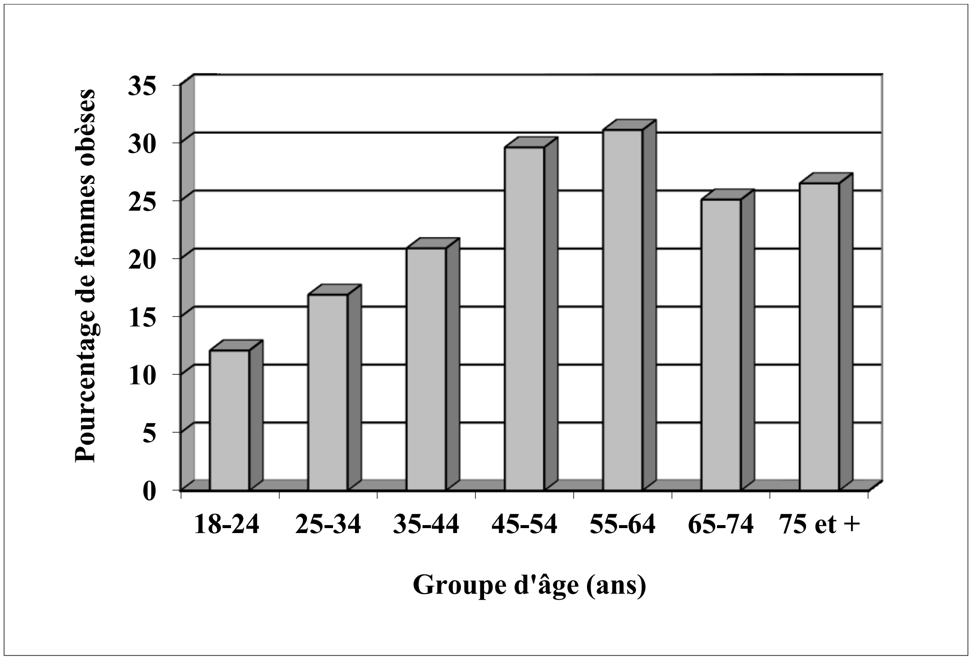

Figure 1.2. Prévalence de l'obésité chez la femme de 18 ans et plus selon l'âge au Canada. Figure adaptée de : Tjepkema, 2005 [34] .

D'importantes fluctuations du poids corporel peuvent être observées à différentes périodes de la vie d'une femme la rendant ainsi plus vulnérable à une augmentation du risque de développer l'obésité et des problèmes de santé [11-12]. La transition ménopausique représente l'une de ces périodes propices au changement de poids corporel chez la femme [13].

1.3.1 Définition de la ménopause

La ménopause est un phénomène physiologique naturel marquant la fin de la fertilité. Elle se produit généralement entre 45 et 55 ans, à un âge moyen estimé à 51 ans [20]. Trois phases déterminent l'ensemble de la période qui englobe la ménopause : la transition ménopausique, la ménopause et la post-ménopause (**Figure 1.3**) [136]. La transition ménopausique renvoie à la période précédant le dernier cycle menstruel au cours de laquelle les fluctuations des concentrations hormonales et les irrégularités du cycle menstruel sont généralement accentuées [136]. Elle débute en moyenne vers l'âge de 45 ans, mais peut débuter n'importe quand entre 39 et 51 ans [20]. Elle s'étend généralement sur une période de 2 à 8 ans (5 ans en moyenne) [20]. Le début de la transition ménopausique est identifié lorsque la femme rapporte avoir au moins trois, mais moins de douze, périodes consécutives d'aménorrhée [20]. Les termes périménopause et transition ménopausique sont souvent utilisés de façon interchangeable, toutefois il est important de préciser la différence entre ces deux termes (voir **Figure 1.3**). En effet, le terme transition ménopausique inclut seulement la portion de la périménopause avant la dernière période de menstruation, tandis que la périménopause inclut l'année suivant la dernière période de menstruation [137-138]. La ménopause, caractérisée par l'arrêt définitif du fonctionnement des ovaires, correspond au dernier cycle menstruel, lequel est déterminé après 12 mois d'aménorrhée et une valeur de l'hormone folliculo-stimulante (FSH) > 30 IU/L [136]. Enfin, la post-ménopause correspond à la période qui suit le dernier cycle menstruel, et ce, jusqu'à la fin de la vie [136].

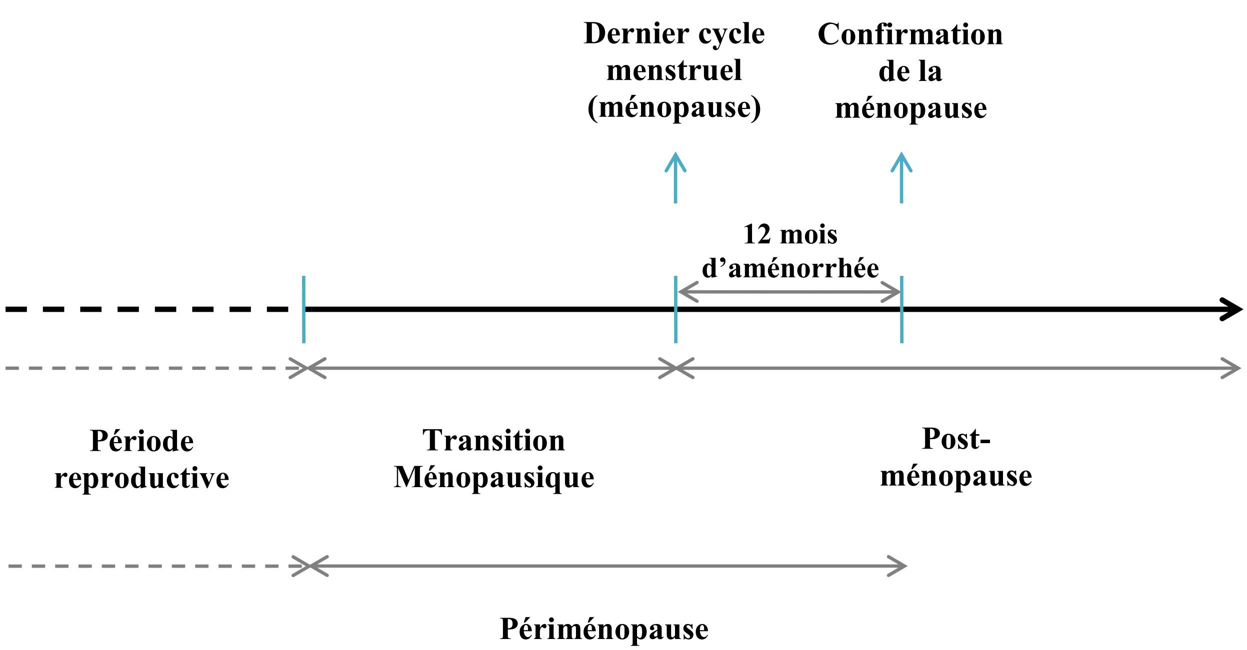

Figure 1.3. Les phases de la ménopause.

1.3.2 Gain de poids pendant la transition ménopausique

La prise de poids à la ménopause est une réalité pour de nombreuses femmes. La plupart des chercheurs qui se sont intéressés à l'évolution du poids en fonction de l'âge décrivent une augmentation linéaire du poids de 20 à 56 ans, sans accentuation particulière durant la transition ménopausique [139]. Dans une étude prospective qui s'est déroulée sur trois ans auprès de 541 femmes âgées de 42 à 50 ans, la moyenne annuelle de gain de poids était de 0,8 kg, mais avec une variation individuelle, puisque 20 % des femmes avaient pris plus de 1,5 kg par année alors que 3 % avaient perdu plus de 1,5 kg [15]. Aucune différence n'a été notée entre le gain de poids moyen des femmes qui sont restées préménopausées et celui des femmes qui sont devenues post-ménopausées [15]. De même, parmi les participantes à la *« Study of Women's Health Across the Nation (SWAN) »*, l'IMC des femmes post-ménopausées ne différait pas significativement de celui des femmes préménopausées après un ajustement pour l'effet de l'âge [140]. La prise de poids observée durant la transition ménopausique apparaît donc principalement comme le résultat du processus normal de vieillissement.

En plus d'un gain de poids, une modification de la composition corporelle peut également survenir lors de la transition ménopausique. En effet, une perte de masse maigre, une augmentation de la masse grasse ainsi qu'une modification de la distribution du tissu adipeux sont souvent observées. Avec la transition ménopausique, le tissu adipeux a tendance à s'accumuler au niveau abdominal plutôt qu'au niveau des hanches et des cuisses. Il est bien documenté que la répartition abdominale des graisses est liée à un risque de développer une maladie cardiovasculaire et le diabète de type 2 plus élevé [141].

Il est généralement reconnu que le gain de poids observé durant la transition ménopausique est dû davantage à l'âge qu'aux changements hormonaux caractérisés principalement par une carence en œstrogènes. Cependant, les changements dans la composition corporelle et la distribution du tissu adipeux durant la transition ménopausique sont matière à controverse. Selon plusieurs études transversales, les femmes post-ménopausées ont une masse adipeuse totale plus élevée et une masse maigre plus faible que les femmes préménopausées [16, 142], mais d'autres études ne montrent aucune différence [143]. Ces résultats divergents pourraient s'expliquer entre autres par les méthodes utilisées pour évaluer la composition corporelle (ostéodensitométrie à absorptiométrie bi-photonique (DXA) *vs* rapport taille/hanches et IMC) ainsi que par les caractéristiques des sujets (âge, IMC). Selon les quelques études longitudinales portant sur le sujet, les changements dans la composition corporelle pourraient s'expliquer non seulement par l'avancée en âge, mais aussi par le vieillissement ovarien, dont la concentration progressivement plus élevée de FSH et la diminution de la sécrétion d'œstrogènes [14, 18]. Les études portant sur la distribution du tissu adipeux sont un peu plus concluantes. Durant la transition ménopausique, il y aurait augmentation de l'adiposité abdominale, et ce, indépendamment de l'âge [18, 144]. Les œstrogènes sont à l'origine de la répartition typiquement féminine des graisses. Par conséquent, les modifications dans la composition corporelle des femmes post-ménopausées pourraient être attribuables à la diminution progressive du taux d'œstrogènes durant la transition ménopausique.

Si les changements hormonaux et le vieillissement semblent jouer un rôle dans le gain de poids et la modification de la composition corporelle durant la transition ménopausique, d'autres facteurs, tels que les habitudes de vie, peuvent atténuer, voire prévenir ces changements.

1.3.3 Effet de la transition ménopausique sur l'équilibre énergétique

Le changement de poids et de composition corporelle durant la transition ménopausique a fait l'objet de plusieurs études [14, 16, 18-19, 145-146], mais on en compte peu sur les facteurs associés à l'équilibre énergétique [18]. La détermination de facteurs modifiables pouvant avoir un effet sur le poids et/ou la composition corporelle durant la transition ménopausique est pourtant primordiale du point de vue de la santé des femmes.

1.3.3.1 Dépense énergétique

a) Métabolisme de repos

La baisse du métabolisme de repos est l'un des facteurs pouvant être associés à la prise de poids durant la transition ménopausique. Bien que le métabolisme de repos diminue avec l'âge, la diminution de la fonction ovarienne et la perte de la phase lutéale du cycle menstruel ainsi que la diminution de la masse musculaire observées chez les femmes post-ménopausées pourraient également être associées à une baisse du métabolisme de repos [147]. Une étude longitudinale échelonnée sur une période de quatre ans a montré une baisse significative du métabolisme de repos avec l'âge [18]. Cependant, cette baisse était 1,5 fois plus élevée chez les femmes post-ménopausées comparativement aux femmes préménopausées [18].

b) Dépense énergétique associée à l'activité physique

Une diminution de la dépense énergétique associée à l'activité physique durant la transition ménopausique a été rapportée dans plusieurs études [148-149]. En fait, il s'agit d'une des observations les plus fréquentes. Dans l'étude longitudinale de Lovejoy *et al.* [18], la dépense énergétique associée à l'activité physique, mesurée par accélérométrie, a diminué de 30 % pendant la transition ménopausique, et la diminution de la dépense énergétique totale, mesurée à l'aide d'une chambre calorimétrique, a diminué d'environ 200 kcal/jour. Cette étude a également montré une diminution de l'oxydation des lipides de 32 % chez les femmes devenues post-ménopausées.

Ainsi, les changements dans la dépense énergétique (diminution du métabolisme de repos, de la dépense énergétique associée à l'activité physique et de l'oxydation des lipides) sont des déterminants importants du gain de poids observé durant la transition ménopausique.

1.3.3.2 Apport énergétique

a) Apport calorique et type de macronutriments ingérés

La prise alimentaire chez l'humain est un phénomène complexe régulé par des facteurs biologiques, environnementaux et comportementaux. Même si on a observé chez les animaux qu'une diminution de la sécrétion d'œstrogènes pouvait entraîner une augmentation de l'apport calorique [150], les effets de la ménopause sur cette composante de l'apport énergétique ne sont pas démontrés chez l'humain. Les quelques études portant sur le sujet révèlent soit des apports caloriques similaires entre les femmes préménopausées et post-ménopausées, soit une légère diminution du nombre de calories ingérées durant la transition ménopausique [18, 149, 151]. Cette diminution de l'apport calorique pourrait s'expliquer par le fait que des femmes auraient tendance à amorcer une démarche d'amaigrissement en réponse à l'augmentation de leur poids [152]. En ce qui concerne le type de macronutriments ingérés, une diminution de l'apport en protéines et en fibres lors de la transition ménopausique a été observée [18]. Cela pourrait avoir une incidence sur le contrôle du poids corporel à long terme, car ces deux macronutriments jouent un rôle important dans l'atteinte de la satiété [153]. Même si aucune différence n'a été observée en ce qui concerne l'apport en lipides, la diminution de l'oxydation des lipides chez les femmes post-ménopausées laisse croire qu'une alimentation faible en gras pourrait être bénéfique pour les femmes à l'approche de la ménopause. Une étude clinique échelonnée sur une période de cinq ans a montré qu'une alimentation faible en gras (25 %) était associée à un meilleur maintien du poids pendant la transition ménopausique [154].

b) Fréquence des repas

Jusqu'à présent, l'influence de la fréquence des repas sur la composition corporelle des femmes préménopausées et post-ménopausées a été évaluée dans une seule étude transversale [24]. Dans cette étude, même si la fréquence des repas était positivement corrélée avec l'apport calorique dans les deux groupes, la fréquence des repas n'était pas reliée à l'adiposité chez les femmes préménopausées, contrairement aux femmes post-ménopausées. L'une des explications suggérée pour expliquer ces résultats est que la fréquence des repas ne serait pas associée à un style de vie actif chez les femmes post-ménopausées, contrairement aux femmes préménopausées [24].

c) Comportements alimentaires et appétit

À notre connaissance, aucune étude n'a examiné le changement au niveau des comportements alimentaires et de l'appétit pendant la transition ménopausique. Cependant, Sowers et al. [155] ont observé un niveau plus élevé de ghréline, hormone qui stimule l'appétit, pendant la transition ménopausique en comparaison aux femmes pré- et post-ménopausées. Ces résultats laissent sous-entendre la présence d'un niveau d'appétit plus élevé pendant la transition ménopausique, ce qui pourrait prédisposer à une consommation plus grande de calories et ainsi entraîner une prise de poids. Toutefois, cette hypothèse reste à être confirmée.

Les changements de poids et/ou de composition corporelle durant la transition ménopausique semblent donc être plus le résultat d'une diminution de la dépense énergétique principalement associée au métabolisme de repos, à l'activité physique et à une diminution de l'oxydation des lipides que d'une augmentation de l'apport énergétique. Pendant la transition ménopausique, la femme doit composer avec une dépense énergétique moindre d'environ 200 kcal/jour. Par conséquent, si l'apport calorique reste le même, il en résultera une prise de poids. Les changements dans les facteurs associés à l'équilibre énergétique durant la transition ménopausique sont résumés à la **Figure 1.4**.

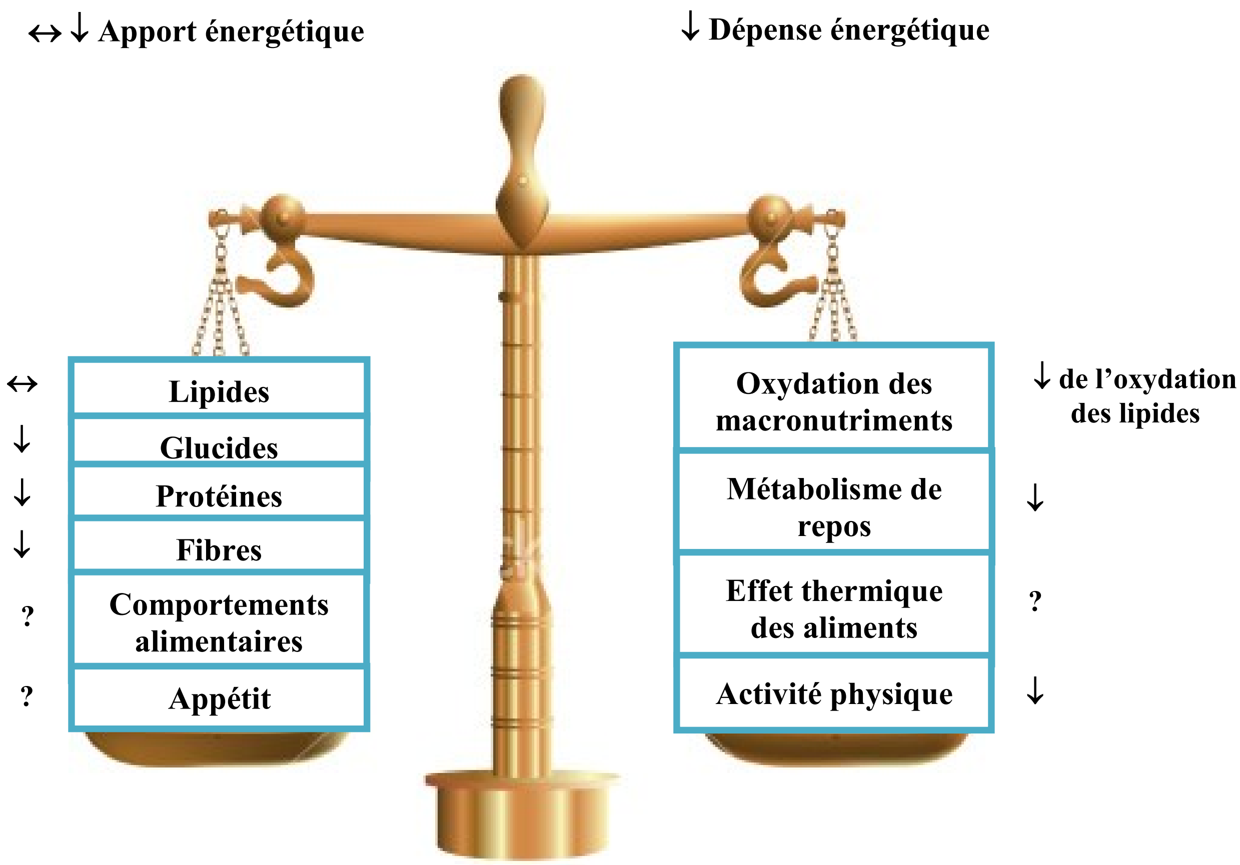

Figure 1.4. Changements dans les facteurs associés à l'équilibre énergétique durant la transition ménopausique.

Légende : ↓ = diminution; ↑ = augmentation; ↔ = aucun changement; ? = aucune étude n'a été réalisée sur le sujet.

1.4 Contribution de la thèse au domaine de la santé des populations

Selon le Comité consultatif fédéral-provincial-territorial sur la santé de la population, « la santé de la population désigne la santé d'une population telle qu'elle est mesurée par des indicateurs de l'état de santé et telle qu'elle est influencée par les environnements social, économique et physique, les habitudes de santé personnelles, la capacité individuelle et les aptitudes à l'adaptation, la biologie humaine, le développement de la petite enfance et les services de santé » [156-157]. Une approche axée sur la santé des populations a comme objectifs principaux de maintenir et d'améliorer l'état de santé de la population en général et de réduire les inégalités de santé [157]. Une telle approche tient compte de l'ensemble des facteurs individuels et collectifs qui ont une influence sur la santé ainsi que leurs interactions [157-158]. Par conséquent, dans une approche axée sur la santé des populations et visant à mieux comprendre l'obésité, il est important d'examiner aussi bien les déterminants individuels (physiologiques, comportementaux) que les déterminants propres à la collectivité (environnementaux, sociaux, politiques).

Les lignes directrices canadiennes sur la prévention et la prise en charge de l'obésité visent à : 1) établir un guide factuel sur le dépistage, la prévention et le traitement de l'obésité au Canada; 2) formuler des recommandations quant aux interventions potentielles pouvant être bénéfique tant au niveau individuel que populationnel; 3) diffuser des documents d'informations pertinentes aux prestataires de soins de santé; 4) aider à élaborer des politiques publiques sur la santé; et à 5) cerner les lacunes au niveau des connaissances et suggérer des pistes de recherches [5]. Les lignes directrices représentent donc un guide pouvant être utilisé tant par les professionnels de la santé que par les décideurs politiques afin de favoriser la prise en charge, la prévention et la diminution de la prévalence de l'obésité par le biais d'interventions adéquates à tous les niveaux de la société (individuel, environnemental, social, politique).

Selon les dernières lignes directrices canadiennes sur la prévention et la prise en charge de l'obésité [5], le succès du contrôle du poids corporel repose sur l'adoption de multiples stratégies d'interventions. En effet, pour intervenir efficacement, il est primordial d'agir au niveau des comportements individuels tout en instaurant un environnement et des conditions de vie propices à l'adoption de saines habitudes de vie [159-160]. La toile causale proposée par le Groupe de travail international sur l'obésité (IOTF) illustre bien la multicausalité de la problématique du poids ainsi que l'interaction entre les divers déterminants et le besoin d'intervenir à de multiples niveaux (**Figure 1.5**).

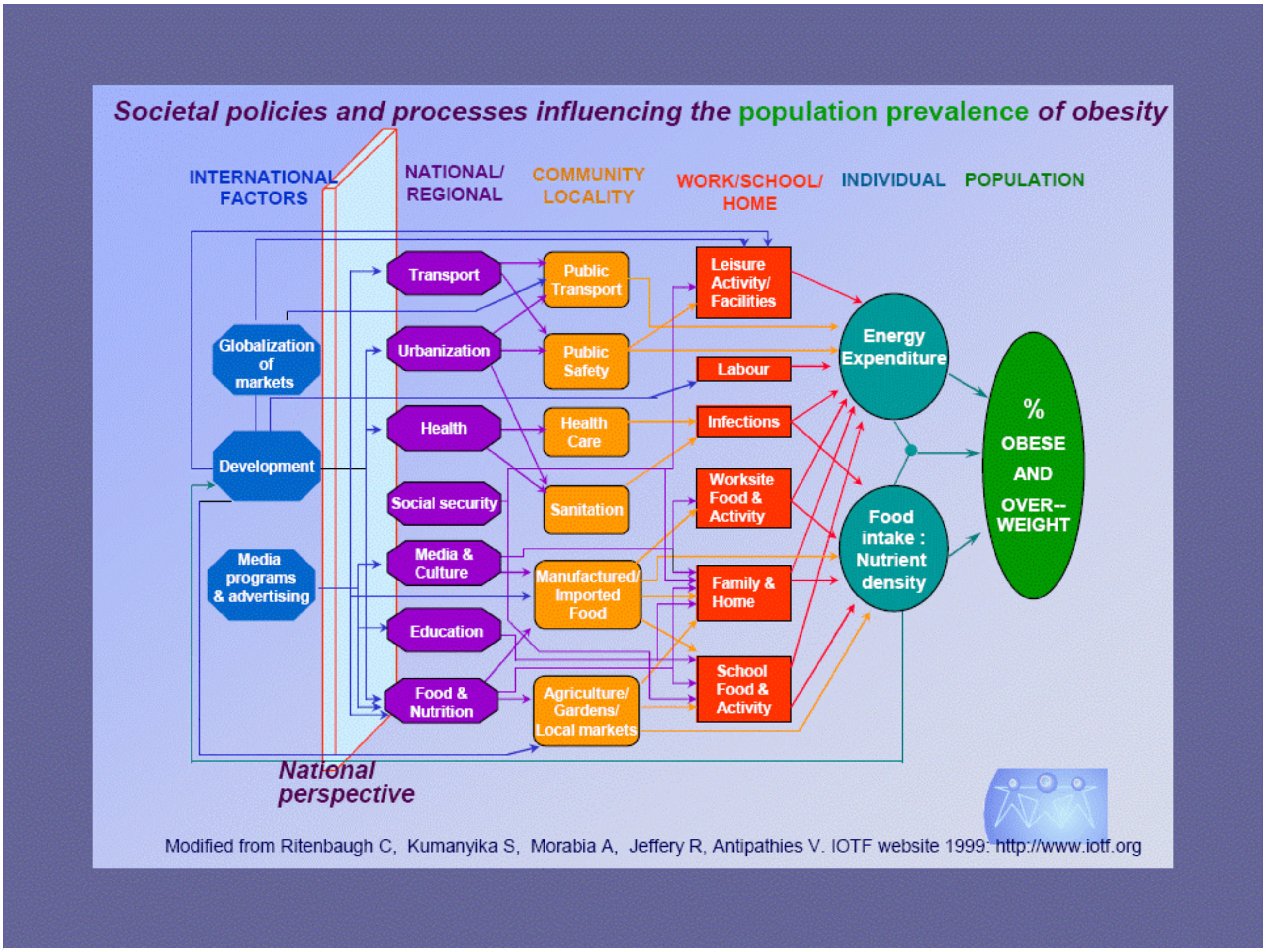

Figure 1.5. Toile causale de la problématique du poids selon une approche de santé des populations.

Figure adaptée de : Kumanyika et al., 2002 [161] et Raine, 2004 [3].

Un algorithme d'évaluation et de prise en charge de l’embonpoint et de l’obésité a été proposé par Lau et al. [5] (**Figure 1.6**). Cet algorithme présente plusieurs recommandations quant aux interventions adéquates pour perdre du poids. Cependant, nous retrouvons très peu d’informations au sujet des interventions efficaces pour assurer le maintien du poids perdu, ce qui est essentiel dans une société où la prévalence de l’obésité est croissante. De plus, les lignes directrices actuelles ne tiennent pas compte de certains sous-groupes de la population susceptibles de gagner du poids tels que les femmes ménopausées. Par conséquent, par ses objectifs visant à obtenir une meilleure connaissance des déterminants associés au maintien de poids et au contrôle du poids corporel pendant la transition ménopausique, les résultats de la présente thèse pourront permettre de bonifier éventuellement les lignes directrices sur la prévention et la prise en charge de l'obésité et ainsi élaborer des stratégies d'interventions efficaces visant à améliorer la santé de la population.

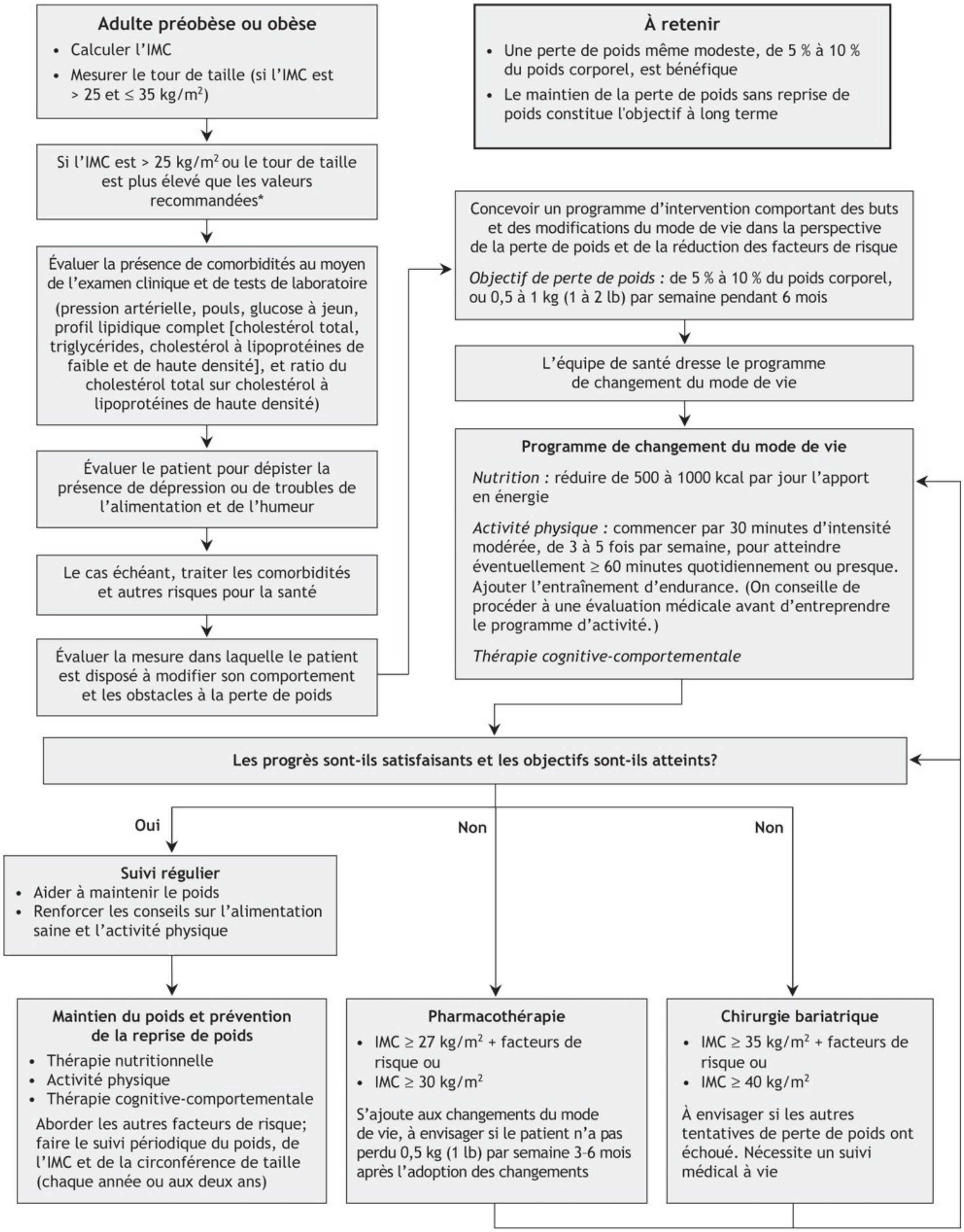

Figure 1.6. Algorithme d'évaluation et étapes de prise en charge de l'adulte pré-obèse ou obèse.

Figure tirée de : Lau et al., 2007 [5].

CHAPITRE 2

MÉTHODOLOGIE

2.1 Résumé et pertinence des études réalisées

Les projets de recherche qui constituent cette thèse de doctorat découlent de la problématique associée au contrôle du poids corporel chez la femme, telle qu'exposée dans le Chapitre 1. Cette problématique peut être résumée comme suit. Bien que les stratégies de perte de poids actuelles permettent généralement d'induire une réduction de poids corporel à court terme, le maintien à long terme du poids perdu ne s'observe que chez une minorité de gens. Certaines études ont montré des résultats intéressants au sujet des facteurs caractérisant les individus qui réussissent à maintenir une perte de poids à long terme. Cependant, celles-ci proviennent en majorité des États-Unis et ont été réalisées principalement à l'aide de questionnaires ou de sondages [122]. D'autres études utilisant des mesures directes d'évaluation des déterminants associés au maintien de poids sont donc nécessaires. De plus, une fluctuation du poids ainsi que des changements dans la composition corporelle se traduisant par une augmentation de la masse adipeuse totale et abdominale et une diminution de la masse maigre lors de la transition ménopausique ont été observés. Ces changements augmentent le risque de développer des problèmes de santé. Bien que les changements hormonaux et le vieillissement semblent jouer un rôle dans le gain de poids et la modification de la composition corporelle durant la transition ménopausique, d'autres facteurs, tels que les habitudes de vie, peuvent permettre d'atténuer, voire de prévenir ces changements. Le changement de poids et de composition corporelle durant la transition ménopausique a fait l'objet de plusieurs études, mais on en compte peu sur les facteurs associés à l'équilibre énergétique. À notre connaissance, une seule étude longitudinale utilisant des mesures directes d'évaluation de la dépense énergétique et de la composition corporelle a été réalisée [18]. La détermination de facteurs modifiables pouvant avoir un effet sur le poids et/ou la composition corporelle durant la transition ménopausique est pourtant primordiale du point de vue de la santé des populations. Une meilleure compréhension des déterminants physiologiques et comportementaux associés au contrôle du poids corporel pendant la transition ménopausique apparaît donc nécessaire.

2.2 Objectifs et hypothèses

2.2.1 Objectif général et description des projets de recherche

L'objectif général des travaux présentés dans cette thèse consiste à identifier les facteurs physiologiques et comportementaux du poids corporel chez la femme. Afin d'atteindre cet objectif, deux études ont été réalisées. Dans un premier temps, à l'aide d'une étude transversale comparant des femmes préménopausées ayant réussi à maintenir une perte de poids d'au moins 6,8 kg (15 lb) depuis plus d'un an à des femmes préménopausées n'ayant jamais eu de problème de poids (femmes préménopausées du projet MONET), nous nous sommes attardés à identifier les facteurs physiologiques et comportementaux pouvant jouer un rôle dans le maintien d'une perte de poids à long terme chez la femme. Cette étude fait référence à un projet de recherche qui s'intitule « projet WiLMa ». Dans un deuxième temps, une étude longitudinale d'une durée de 5 ans, réalisée auprès de femmes préménopausées susceptibles de traverser les différentes phases de la ménopause pendant la durée de l'étude, nous a permis de mesurer l'impact de la transition ménopausique sur certains facteurs physiologiques et comportementaux associés à l'équilibre énergétique. Cette étude fait référence à un projet de recherche qui s'intitule « projet MONET ».

2.2.2 Objectifs spécifiques et hypothèses de recherche

Notre premier objectif spécifique consiste à identifier les facteurs physiologiques et comportementaux susceptibles de favoriser le maintien d'une perte de poids à long terme chez la femme préménopausée (projet WiLMa). Les résultats de cette étude sont présentés au Chapitre 3. Cet objectif nous amène à poser l'hypothèse selon laquelle les femmes ayant réussi à maintenir une perte de poids d'au moins 6,8 kg (15 lb) depuis plus d'un an ont, en comparaison à des femmes préménopausées n'ayant jamais eu de problème de poids, une plus grande dépense énergétique reliée à l'activité physique, mangent plus fréquemment, ont un comportement alimentaire plus restrictif et ont un apport calorique plus faible. De plus, elles ont un appétit plus élevé ainsi qu'une dépense énergétique de repos plus basse.

Notre deuxième objectif spécifique a pour but de mesurer la relation entre la fréquence des repas et la composition corporelle des femmes préménopausées en tenant compte de leur niveau d'activité physique (analyse transversale en utilisant les données de l'année 1 du projet MONET). Les résultats de cette étude sont présentés au Chapitre 4. Cet objectif nous amène à émettre l'hypothèse que l'effet de la fréquence des repas sur la composition corporelle des femmes préménopausées est influencé par le niveau d'activité physique. Nous suggérons donc que les femmes qui mangent plus souvent peuvent avoir un niveau d'adiposité plus faible en raison du fait qu'elles ont un niveau d'activité physique plus élevé.

Notre troisième objectif spécifique consiste à mesurer l'impact de la transition ménopausique sur les facteurs physiologiques et comportementaux associés à l'équilibre énergétique (projet MONET). Les résultats de cette étude sont présentés aux Chapitre 5 et 6. Le Chapitre 5 présente l'effet de la transition ménopausique sur les déterminants associés à la dépense énergétique tandis que le Chapitre 6 traite des déterminants associés à l'apport alimentaire et à l'appétit. Cet objectif nous amène à suggérer les hypothèses suivantes : 1) la transition ménopausique est accompagnée d'une diminution de la dépense énergétique totale, principalement due à une diminution de la pratique d'activité physique et de la dépense énergétique de repos (Chapitre 5); 2) la transition ménopausique est accompagnée d'une augmentation de l'apport calorique et de l'appétit (Chapitre 6).

2.3 Description et justification des méthodes utilisées

Dans le cadre des deux études présentées dans cette thèse, les participantes étaient invitées à prendre part à deux visites expérimentales où une évaluation standardisée de la composition corporelle, de la dépense énergétique, de l'apport alimentaire et de la condition cardio-respiratoire a été réalisée. Pour ce faire, des méthodes et des techniques à la fine pointe de la technologie permettant d'obtenir des mesures précises et directes de ces phénotypes ont été utilisées. Parmi ces méthodes on retrouve le DXA pour évaluer la composition corporelle; l'accélérométrie pour mesurer la dépense énergétique associée à l'activité physique; la calorimétrie indirecte pour évaluer la dépense énergétique de repos et l'effet thermique des aliments; un test à l'effort maximal pour évaluer la condition cardio-respiratoire ($VO_{2\ peak}$); un journal alimentaire pour mesurer l'apport énergétique quotidien ainsi que la fréquence des repas; un repas standardisé de type buffet pour évaluer l'apport alimentaire spontané et des questionnaires mesurant les comportements alimentaires et l'appétit. La **Figure 2.1** présente un schéma de l'évaluation des participantes lors de la première visite expérimentale qui avait lieu pendant la phase folliculaire du cycle menstruel après 12 heures de jeûne. La seconde visite expérimentale consistait en une évaluation de la condition cardio-respiratoire des participantes. La collecte des données a été effectuée à l'Unité de Recherche sur le Comportement et le

Métabolisme (URCM). Dans le cadre de l'étude WiLMa, les données ont été collectées à une seule occasion. En ce qui concerne l'étude MONET, l'évaluation des participantes a été effectuée à cinq reprises, soit une fois à chaque année pendant cinq ans. Bien que chacun des articles de cette thèse (Chapitres 3 à 6) décrivent en détail les méthodes utilisées, d'autres détails méthodologiques ainsi qu'une justification des méthodes utilisées sont présentés dans les pages suivantes.

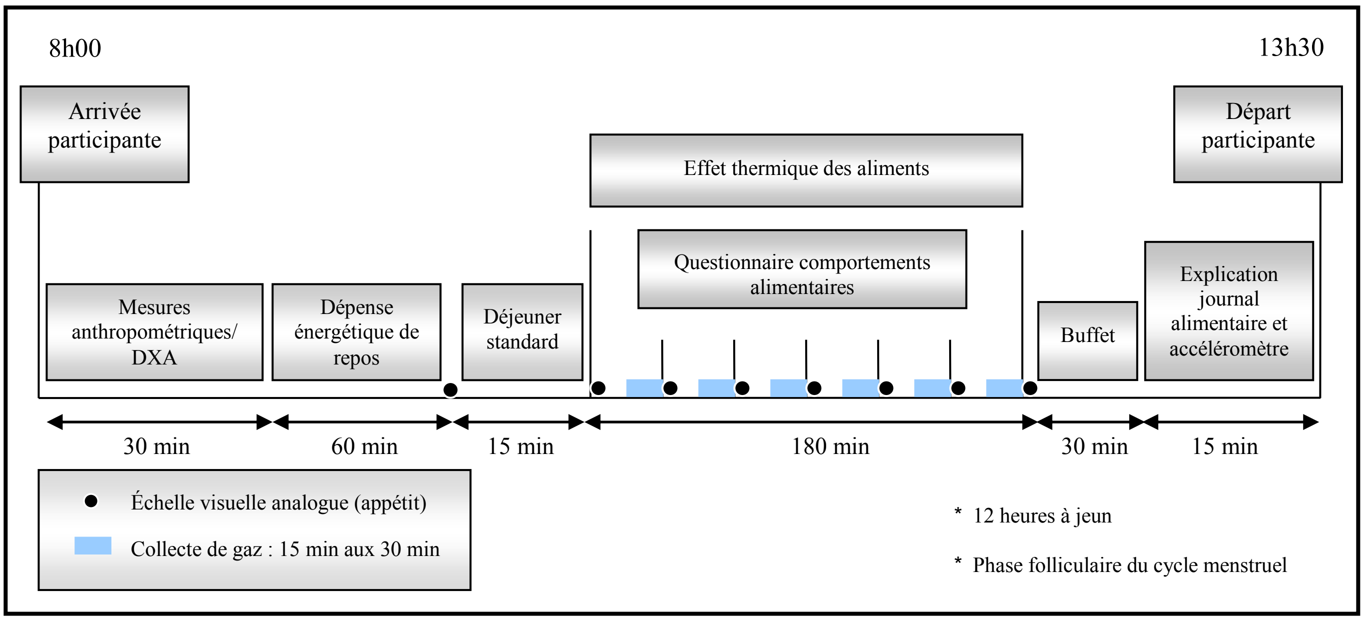

Figure 2.1. Schéma de la première visite expérimentale.

2.3.1 Mesures anthropométriques et de la composition corporelle

Des mesures anthropométriques telles que le poids corporel, la taille et la circonférence de la taille ont été mesurées. Une standardisation de ces mesures a été effectuée afin d'éviter les biais et les erreurs de mesures. Pour ce faire, les participantes devaient se vêtir d'une jaquette d'hôpital et ne pas porter de souliers. Le poids corporel et le taille ont été mesurés à l'aide d'une balance digitale (BWB-800AS digital scale) et d'un stadiomètre Tanita HR-100 (Tanita Corporation of

America, Inc., Arlington Heights, IL), respectivement. La circonférence de la taille a été quant à elle mesurée à l'aide d'un ruban à mesurer conventionnel. Le point milieu entre la dernière cote flottante et la partie supérieure de la crête iliaque a été utilisé comme marqueur de référence. La moyenne obtenue suite à la prise de deux mesures a été utilisée comme valeur finale. L'évaluation de la composition corporelle a été réalisée à l'aide du DXA (ostéodensitométrie à absorptiométrie bi-photonique; GE-LUNAR Prodigy module, GE Medical Systems, Madison, WI, USA) qui consiste au passage d'un rayon-X de faible intensité de la tête au pied. Cette méthode permet de mesurer avec précision la densité osseuse, la masse adipeuse, le pourcentage de gras et la masse musculaire. Bien que plusieurs méthodes soient disponibles, le DXA a été choisi, car il est considéré comme étant une des meilleures méthodes pour évaluer de façon précise et valide la composition corporelle [162]. Des coefficients de variation et de corrélation pour le pourcentage de gras mesuré chez 12 sujets en santé testé dans notre laboratoire étaient 1,8% et r = 0,99, respectivement.

2.3.2 Dépense énergétique de repos

La dépense énergétique de repos a été évaluée par calorimétrie indirecte sous « canopy ». Cette méthode vise à établir la dépense énergétique de repos en se basant sur la consommation d'oxygène et la production de dioxyde de carbone [163]. Pendant cette mesure, les participantes étaient allongées dans un lit et un casque de plastique transparent (« canopy ») était placé sur leur tête afin de mesurer les échanges gazeux pendant une période de 30 minutes. La mesure débutait après une période de repos de 30 minutes. La calorimétrie indirecte est la méthode la plus utilisée pour évaluer la dépense énergétique de repos des individus [163]. De plus, elle est plus facile d'utilisation et beaucoup moins coûteuse que la méthode de calorimétrie directe [163].

2.3.3 Effet thermique des aliments

Suite à la mesure de la dépense énergétique de repos, un déjeuner standard était offert aux participantes. Ce dernier était constitué de 2 tranches de pain de blé entier, 2 petits contenants de beurre d'arachide, 2 petits contenants de confiture aux framboises, un morceau de fromage cheddar et deux petits jus d'orange (575 kcal). La standardisation du déjeuner nous a permis de pouvoir comparer la dépense énergétique des participantes associée à l'effet thermique des aliments. L'effet thermique des aliments a été mesuré pendant les 3 heures qui ont suivi la prise du déjeuner. Cette mesure permet de mesurer la quantité de calories dépensée suite à l'ingestion d'un repas. L'effet thermique des aliments a été évalué essentiellement de la même façon que la dépense énergétique de repos, soit par calorimétrie indirecte sous « canopy » pour une période de 15 minutes en alternance avec 15 minutes de repos.

2.3.4 Dépense énergétique associée à l'activité physique

La dépense énergétique associée à l'activité physique a été mesurée à l'aide du port d'un accéléromètre pour une période de 7 jours (Actical; Mini Mitter Co, Inc., Bend, OR, USA). L'Actical a été validé pour la mesure de l'activité physique chez les adultes [164] et montre une meilleure fiabilité que d'autres modèles d'accéléromètres [165]. L'accélérométrie permet d'évaluer la dépense énergétique quotidienne associée à la pratique d'activité physique dans des conditions habituelles de vie en mesurant les déplacements du corps humain dans l'espace [166]. Tous les mouvements du tronc et des membres induisent des accélérations qu'il est possible de mesurer par des accéléromètres. Les accélérations et décélérations enregistrées rendent compte de la fréquence et de l'intensité de l'effort physique produit par le corps, ce qui est beaucoup plus précis que les résultats obtenus avec les podomètres [166]. Lors de cette mesure, les participantes devaient porter l'accéléromètre du moment où elles se levaient du lit le matin jusqu'au moment où elles allaient se coucher le soir, et ce pendant 7 jours consécutifs. Cette durée a été choisie, car il a été rapporté qu'une période de 7 jours permet d'obtenir une mesure de l'activité physique fiable à 90% chez les hommes et les femmes [167]. L'accéléromètre a été porté au niveau de la hanche, car cet emplacement est considéré comme étant le meilleur prédicateur de la dépense énergétique à comparer avec d'autres emplacements tels que le pied, la tête, le tronc, la main et le bras (r = 0,92-0,97) [168].

2.3.5 Apport alimentaire

a) Journal alimentaire

Afin d'obtenir de l'information sur l'apport alimentaire des participantes, un journal alimentaire de 7 jours a été complété. Cette méthode d'évaluation de l'apport alimentaire est la plus appropriée pour examiner les diètes, acquérir de l'information au sujet du type de nourriture, de la fréquence des repas et des collations consommés [169]. De plus, elle permet d'avoir un portrait global (semaine et fin de semaine) de l'alimentation des participantes, ce qui est important en sachant que la plupart des gens ne consomme pas la même quantité et le même type de nourriture selon les jours de la semaine. Le journal alimentaire a été complété pour une durée de 7 jours de façon simultanée avec le port de l'accéléromètre, ce qui a permis de pouvoir comparer l'énergie ingérée avec l'énergie dépensée. Lors de cette mesure, les participantes devaient indiquer le type et la quantité des aliments et boissons qu'elles consommaient. Le temps et le lieu où les aliments ont été consommés étaient également notés. Les participantes recevaient oralement et par écrit des instructions sur la façon de compléter le journal alimentaire. Elles étaient invitées à être le plus précis possible dans leur description en indiquant tous les principaux ingrédients ainsi que la quantité, la marque des produits et la méthode de cuisson. Il était également suggéré aux participantes d'apporter les étiquettes nutritionnelles des aliments consommés, lorsque possible, afin de faciliter l'analyse des journaux alimentaires. Ces derniers étaient soigneusement vérifiés lors de leur retour afin de s'assurer qu'aucune information n'était manquante. Les journaux alimentaires ont été analysés par une diététiste à l'aide du logiciel « *Food Processor SQL* » (version 9.6.2 et 10.8; ESHA Research, Salem OR) afin d'évaluer l'apport calorique ainsi que l'apport en macronutriments (fibres, protéines, lipides, glucides).

b) Repas standardisé de type buffet

Afin de mesurer l'apport alimentaire spontané, un repas standardisé de type buffet a été offert aux participantes à l'heure du dîner (3 heures après le déjeuner standard) où elles étaient invitées à manger la quantité et la qualité des aliments qu'elles désiraient [170-172]. Tous les aliments étaient pesés avant et à la fin du buffet au gramme près. L'apport calorique ainsi que l'apport en macronutriments (fibres, protéines, lipides, glucides) ont été calculées avec le programme Food Processor SQL (version 9.6.2 et 10.8; ESHA Research, Salem, OR).

2.3.6 Fréquence des repas

Les données obtenues à l'aide des journaux alimentaires ont également été utilisées pour mesurer la fréquence quotidienne des repas. La fréquence des repas a été définie comme toute occasion où de la nourriture est consommée [95]. Cette définition excluait les boissons (boissons alcoolisées, boissons gazeuses, jus de fruit, eau, café, thé) qui ont été consommés en absence de nourriture. Lorsque deux occasions de manger avaient lieu en moins de 15 minutes, chacune d'entre elles était comptée comme étant une seule occasion. Lorsque plus de 15 minutes séparaient deux occasions, celles-ci étaient considérées comme deux occasions distinctes. Cette méthode de mesure de la fréquence des repas a été décrite précédemment [95, 173-174]. Plus amples informations sur la mesure de la fréquence des repas ainsi que l'impact de cette variable sur le poids et la composition corporelles sont présentées à l'Annexe A de la présente thèse.

2.3.7 Appétit

Le niveau d'appétit a été mesuré avant et immédiatement après le déjeuner standard ainsi qu'à chaque 30 minutes lors de la mesure de l'effet thermique des aliments. Cette mesure a été réalisée à l'aide d'échelles visuelles analogues de 150 mm adaptée de Hill et Blundell [175]. Ces échelles visuelles analogues permettent d'évaluer le désir de manger, la sensation de faim, le niveau de satiété ainsi que la perception de la quantité de nourriture pouvant être ingérée à l'aide de 4 questions : 1) « Dans quelle mesure avez-vous envie de manger ? » (envie très forte – envie très faible); 2) « Dans quelle mesure avez-vous l'impression d'avoir faim ? » (envie très forte – envie très faible); 3) « À quel point vous sentez-vous rempli ? » (pas rempli du tout – très rempli); 4) « Quelle quantité de nourriture pourriez-vous manger immédiatement ? » (absolument rien – une grande quantité). La mesure effectuée avant le déjeuner standard a été considérée comme étant la valeur à jeun. L'aire sous la courbe des valeurs obtenues pendant la période postprandiale (0, 30, 60, 90, 120, 150 et 180 minutes) a été calculé à l'aide de la méthode des trapèzes [176].

2.3.8 Comportements alimentaires

Les comportements alimentaires tels que la restriction alimentaire, la désinhibition et la susceptibilité à la faim ont été évalués à l'aide de la version française du questionnaire « *The Three-Factor Eating Questionnaire (TFEQ)* » développé par Stunkard et Messick en 1985 [177 73]. La restriction alimentaire réfère à la tendance à restreindre de façon consciente son apport alimentaire afin d'assurer un contrôle de son poids corporel ou engendrer une perte de poids. La désinhibition consiste plutôt à la surconsommation d'aliments en réponse à certains stimuli externes tels que le stress émotionnel. Ce comportement est associé à une perte de contrôle sur la prise alimentaire de même qu'à l'absence de sensation de faim. Quant à la susceptibilité à la faim, elle consiste en la consommation d'aliments en présence de sensations et de perceptions de la faim. Des sous-échelles plus spécifiques de ces trois comportements alimentaires ont été proposées par Westenhoefer et al. [74] et Bond et al. [75]. Dans le cadre de cette thèse, nous avons utilisé le score de deux sous-échelles du comportement de restrictions alimentaires du *TFEQ* : 1) restriction alimentaire rigide (approche de type tout ou rien face à la nourriture consommée, à la diète et au poids) et 2) restriction alimentaire flexible (approche graduelle face la nourriture consommée, à la diète et au poids). Le *TFEQ* possède de bonnes propriétés psychométriques (validité, consistance interne et reproductibilité) et il est souvent utilisé pour évaluer les comportements alimentaires dans un contexte de contrôle du poids corporel [73, 178].

2.3.9 Condition cardio-respiratoire

Cette mesure consiste à évaluer la condition cardio-respiratoire (VO_{2peak}) des participantes lors d'un exercice jusqu'à épuisement. Les participantes devaient s'abstenir de tout exercice vigoureux et de consommation de boissons alcoolisées 6 heures avant le test ainsi que de s'abstenir de manger et de boire du café 2 heures avant le début de la mesure de la condition cardio-respiratoire. Cette mesure consistait en un test de marche, supervisé par un kinésiologue certifié, qui a été effectué sur un tapis roulant. L'intensité de l'exercice a été augmentée à chaque 3 minutes jusqu'à ce que la participante atteigne l'épuisement (Protocole de marche Jean Jobin). Ce test était d'une durée de 10 à 15 minutes. La tension artérielle, la fréquence cardiaque, l'activité électrique du cœur (ECG), la consommation d'oxygène (Vmax 229 series metabolic cart; SensorMedics Corporation), et la perception à l'effort ont été mesurés tout au long du test. Le test a été arrêté lorsqu'au moins deux des critères suivant ont été atteints : 1) fréquence cardiaque maximale prédite atteinte; 2) quotient respiratoire de 1,1; 3) consommation d'oxygène qui demeure stable ou qui diminue avec une augmentation de la charge de travail; 4) perception à l'effort de 19 ou 20 sur l'échelle de Borg [179]. Ce protocole de marche a été utilisé dans plusieurs études effectuées dans notre laboratoire et a montré son efficacité à évaluer avec précision la condition cardio-respiratoire des individus. De plus, ce test est moins exigeant qu'un protocole où les participantes doivent courir, ce qui facilite sa réalisation.

CHAPITRE 3

CARACTÉRISTIQUES DES FEMMES AYANT RÉUSSI À MAINTENIR UNE PERTE DE POIDS À LONG TERME EN COMPARAISON À DES FEMMES N'AYANT JAMAIS EU DE PROBLÈMES DE POIDS : UNE ÉTUDE PILOTE.

Karine Duval, Alexander Schwartz, Mohamed Mamlouk, Irene Strychar, Rémi Rabasa-Lhoret, Denis Prud'homme, Éric Doucet

L'article composant ce chapitre est intitulé :

«Characteristics of successful weight-loss maintainers versus never obese women: A pilot study.»

(Article en préparation)

Contribution des auteurs :

Karine Duval a généré les idées et a participé à toutes les étapes associées à ce projet de recherche (WiLMa) : demande de subvention; développement du projet; recrutement des participantes; collecte, analyse et interprétation des données et rédaction du manuscrit. Alexander Schwartz et Mohamed Mamlouk ont participé à la collecte des données ainsi qu'à la révision du manuscrit. Éric Doucet a supporté la candidate au doctorat, Karine Duval, tout au long du projet en lui donnant de précieux conseils. Éric Doucet, Irene Strychar, Rémi Rabasa-Lhoret et Denis Prud'homme ont participé à l'élaboration du projet duquel proviennent les femmes du groupe contrôle et ont participé à la révision du manuscrit.

RÉSUMÉ

Objectif : L'objectif de cette étude était de comparer les déterminants physiologiques et comportementaux associés à l'équilibre énergétique entre des femmes préménopausées ayant réussi à maintenir une perte de poids à long terme et des femmes préménopausées n'ayant jamais eu de problème de poids.

Méthodes : Vingt-deux femmes qui avaient réussi à maintenir une perte de poids d'au moins 6,8 kg (15 lb) pendant au moins 1 an (âge : 35,9 ± 8,8 ans; IMC : 24,3 ± 3,2 kg/m²) ont été appariées individuellement à 22 femmes qui n'avaient jamais eu de problème de poids (âge : 49,6 ± 1,6 ans; IMC : 23,5 ± 2,7 kg/m²) pour le poids corporel (65,3 ± 9,2 versus 65,0 ± 8,9 kg), la masse adipeuse (20,0 ± 7,4 versus 19,9 ± 6,6 kg) et la masse maigre (44,6 ± 5,0 versus 44,8 ± 4,8 kg). Dans les deux groupes, la composition corporelle (DXA), la dépense énergétique associée à l'activité physique (accéléromètre), la dépense énergétique au repos et l'effet thermique des aliments (calorimétrie indirecte), les variables du *Three-Factor Eating Questionnaire*, l'appétit (échelle visuelle analogue), la fréquence des repas, l'apport calorique et la composition en macronutriments (journal alimentaire de 7 jours et repas de type buffet) ont été mesurés.

Résultats : Il a été observé que les femmes préménopausées qui avaient réussi à maintenir une perte de poids à long terme dépensaient plus de calories par jour associées à l'activité physique (1004,9 ± 248,6 vs 824,9 ± 255,2 kcal, $P < 0,05$), mangeaient plus fréquemment (5,4 ± 0,7 vs 4,4 ± 0,9 occasions de manger/jour, $P < 0,01$), avaient un apport alimentaire plus élevé en protéines (19,0 ± 3,4 vs 15,4 ± 2,7 %, $P < 0,05$), consommaient moins de glucides (243,8 ± 72,2 vs 272,5 ± 77,2 g, $P < 0,05$), et avaient un comportement de restriction alimentaire plus rigide (2,5 ± 1,2 vs 1,4 ± 1,3, $P < 0,05$) que les femmes qui n'avaient jamais eu de problèmes de poids. Aucune

différence significative n'a été notée entre les groupes pour la dépense énergétique de repos, l’effet thermique des aliments, l'apport calorique et l'appétit.

Conclusion : Ces résultats suggèrent que le maintien d’une perte de poids à long terme chez la femme préménopausée est associé à un apport protéinique plus élevé, un contrôle volontaire alimentaire cognitif plus important ainsi qu’à une plus grande dépense énergétique associée à l’activité physique.

Characteristics of Successful Weight-Loss Maintainers versus Never Obese Women: A Pilot Study.

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ABSTRACT

Objectives: The purpose of this study was to compare energy balance-related variables between successful weight-loss maintainers and never obese control women. **Methods:** Twenty-two women who had successfully maintained a weight loss of at least 6.8 kg (15 lbs) for at least 1 year (age: 35.9 ± 8.8 yrs; BMI: 24.3 ± 3.2 kg/m²) were individually matched to 22 women who had never been obese (age: 49.6 ± 1.6 yrs; BMI: 23.5 ± 2.7 kg/m²) for body weight (65.3 ± 9.2 vs. 65.0 ± 8.9 kg), fat mass (20.0 ± 7.4 vs. 19.9 ± 6.6 kg) and fat-free mass (44.6 ± 5.0 vs. 44.8 ± 4.8 kg). In both groups, body composition (DXA), physical activity energy expenditure (PAEE) (accelerometer), resting energy expenditure (REE) and thermic effect of food (TEF) (indirect calorimetry), Three-Factor Eating Questionnaire variables, appetite (visual analogue scale), eating frequency (EF), energy intake (EI) and macronutrient composition (7-day food diary and buffet-type meal) were measured. **Results:** There were significantly higher PAEE (1004.9 ± 248.6 vs. 824.9 ± 255.2 kcal, $P < 0.05$), EF (5.4 ± 0.7 vs. 4.4 ± 0.9 eating occasions, $P < 0.01$), protein intake (19.0 ± 3.4 vs. 15.4 ± 2.7 %, $P < 0.05$), rigid dietary restraint (2.5 ± 1.2 vs. 1.4 ± 1.3, $P < 0.05$), and lower carbohydrate intake (243.8 ± 72.2 vs. 272.5 ± 77.2 g, $P < 0.05$) in the weight-loss maintenance group as compared to women in the never obese control group. No significant differences were noted between groups for REE, TEF, EI, and appetite variables. **Conclusion:** These results suggest that successful weight-loss maintenance is associated to a diet with increased satiating potential, greater cognitive control and increased PAEE.

Keywords: Weight-loss maintenance, women, energy expenditure, dietary intake, appetite, eating behaviours, body composition

INTRODUCTION

The major challenge in the treatment of obesity is maintenance of weight loss. Although current weight loss interventions produce short-term success, sustained weight-loss maintenance is rarely achieved [1]. Indeed, most dieters regain about one third of the weight lost during the next year and they generally return to baseline in 3 to 5 years [2]. Identifying factors that promote successful long-term weight-loss maintenance is, therefore, necessary to improve current weight maintenance strategies.

Previous research has identified common behaviors and strategies associated with long-term weight-loss maintenance. Much of this research has been obtained through the National Weight Control Registry (NWCR). The NWCR, established in 1994, is the largest prospective investigation of long-term successful weight-loss maintenance [3-4]. This registry contains currently more than 5,000 individuals who have lost at least 13.6 kg (30 lbs) and kept it off at least 1 year [3]. Findings from this registry suggest that common behaviors among individuals who succeed at long-term weight loss include: 1) consuming low-energy, low-fat diets [5]; 2) engaging in high levels of regular physical activity, approximately 1 hour of moderately intense physical activity per day [6-8]; 3) self-monitoring body weight on a regular basis - over 75% of registry members report weighing themselves at least once a week [9]; 4) eating breakfast regularly [10]; 5) having a consistent diet across weekdays and weekends [11]; 6) consuming approximately five eating occasions per day [3]; 7) having a higher dietary restraint [12]; and 8) spending a minimal amount of time watching television – 62% of the registry members reported watching 10 or fewer hours of television per week [13].

Previous studies have focused on either energy expenditure (EE) or energy intake (EI) and most of them used self-report measures. To our knowledge, none have addressed both side of the energy balance using more direct measurements, which is important to objectively determine how weight-loss maintenance is achieved. Hence, the present study was performed to extend the emergent line of research on weight-loss maintenance and to determine characteristics associated with successful weight-loss maintenance. The objective of this study was to compare variables related to energy balance of successful weight-loss maintainers to women who have never been obese. We hypothesized that successful weight-loss maintainers, as compared to never obese women, would have higher physical activity EE (PAEE), eating frequency (EF), appetite and level of dietary restraint, and lower EI and resting EE (REE).

METHODS

Participants

Twenty-two women who had successfully maintained a weight loss were individually matched, one by one, on the basis of their body weight, fat mass (FM) and fat-free mass (FFM) to a control group composed of 22 women who had never been obese. The matching criterion was a difference of 3 kg or less for each variable. When more than one possible match could be obtained, the subject with the smallest difference was retained. Volunteers were recruited through advertisements in local newspapers. To be eligible, weight-loss maintainers were included if they met the following criteria: (1) aged between 18 and 50 years, (2) weight loss ≥ 6.8 kg (15 lbs), (3) maintained that weight loss for ≥ 1 year, (4) reported weight stability (± 2 kg) for 6 months or more before enrolment in the study, (5) non-smoker, (6) regular menstrual cycle, and (7) no medical problems that could have interfered with outcome variables including cardiovascular and/or metabolic diseases. To increase the reliability of self-reported weight loss, subjects were asked to provide a "before and after" weight loss picture. Participants in the never obese control group were selected from a cohort of premenopausal women of one of the Montreal, Ottawa, New Emerging Team (MONET) study who had no history of obesity (BMI ≥ 30) [14]. The criteria for participants in the never obese control group also required that they had been weight stable (± 2 kg) for 6 months before enrollment, had regular menstrual cycle, were non-smokers, and had no major health problems. Women were always tested on days 1–8 of the follicular phase of the menstrual cycle, *ie*, when estrogens and progesterone are at their lowest concentrations. This study received approval from the University of Ottawa and the Montfort Hospital ethics committees, and written consent was obtained from each participant.

Anthropometric measurements

Body weight and height were measured with a BWB-800AS digital scale and a Tanita HR-100 height rod (Tanita Corporation of America, Inc, Arlington Heights, IL), respectively, while participants were wearing a hospital gown and no shoes. Body composition was measured by using dual-energy X-ray absorptiometry (DXA; GE-LUNAR Prodigy module; GE Medical Systems, Madison, WI.). Coefficient of variation and correlation for percentage of body fat (%BF) measured in 12 healthy subjects tested in our laboratory were 1.8% and $r = 0.99$, respectively.

Resting EE and Thermic effect of food

Resting EE and thermic effect of food (TEF) were measured by indirect calorimetry (Deltatrac II metabolic cart; SensorMedics, Yorba Linda, CA). Resting EE was measured for 30 min after a 12-h overnight fast. Subjects had to rest quietly in the supine position for 20 min before the measurement. The first and last 5 min were excluded and only those obtained during min 6 to 25 were used in the calculation. The participants then consumed a standardized breakfast consisting of 2 slices of whole wheat bread (80 g), peanut butter (20 g), raspberry jam (20 g), cheddar cheese 27% milk fat (20 g), and orange juice (250 ml). The total energy content was 575 kcal (2400 kJ), and its food quotient was 0.89 (57% carbohydrates, 13% protein, 30% lipids). Subjects ate everything within 10 minutes. For postprandial EE (PEE), 15-min sampling periods were performed every 30 min for 3 h during the postprandial period [15]. A mean value (in kcal/min) for each of the 6 PEE measurements was calculated. The TEF was obtained by subtracting REE from PEE for each of the mean values obtained for the 6 sampling periods. Total TEF was calculated by multiplying the mean value of each of the 6 sampling periods by 30 min. These 6 values were then added together to obtain TEF for the 180-min period. EE was calculated according to the Weir equation [16]. Coefficient of variation and correlation for the determination of REE with the Deltatrac II metabolic cart in our laboratory were 2.3% and r = 0.98, respectively, as determined in 12 healthy subjects.

Physical activity EE

Multidirectional accelerometry units were used (Actical; Mini Mitter Co, Inc, Bend, OR) to measure PAEE. The Actical has been validated to measure physical activity in adults [17] and has shown better instrument reliability than other accelerometers models [18]. It was used to estimate daily EE from physical activities and time spent in various physical activity intensities. Participants were asked to wear the accelerometer upon waking up and took it off just before going to bed for 7 consecutive days. Such a duration was reported to result in 90% reliability for the measurement of PAEE in both males and females [19]. The accelerometer was worn over the right hip as it best predicts EE (r = 0.92– 0.97) [20].

Total EE

Total EE (TEE) was calculated by using the following formula:

$$TEE = (PAEE + REE) \times 1.11 \qquad (1)$$

where the factor 1.11 corresponds at the TEF, and was fixed at 10% of TEE.

Dietary Assessment

Food Diary

Subjects were asked to record the type and amount of food and beverages consumed for 7 consecutive days. The time and place of eating of food were recorded as well. Participants received oral and written instructions on recording their food intake. Recorded data were carefully verified on the return of the food diary to obtain forgotten data or correct misreported data. The diaries were analysed by a registered dietician with the use of the Food Processor SQL program (version 10.8; ESHA Research, Salem, OR) using the 2007 Canadian Nutrient Data File.

Buffet-type meal

A buffet-type meal was used to measure *ad libitum* food intake in an experimental context as previously described [21]. Briefly, a cold buffet-type meal comprising a variety of foods was offered at lunch time (3 hours after a standardized breakfast) and subjects were instructed to eat *ad libitum* [15, 22]. A maximum of 30 min was given to eat their meal. All foods were weighed before and at the end of the buffet to the nearest gram. Energy, protein, lipid, carbohydrate and dietary fiber intakes were calculated with the Food Processor SQL program (version 10.8; ESHA Research, Salem, OR) using the 2007 Canadian Nutrient Data File.

Establishing the number of eating occasions

Data from the food diaries were also used to calculate the average number of eating occasions per day, *ie*, EF. Eating occasions were defined as any occasion when food was consumed [23]. The definition excluded drinks (alcoholic drinks, soft drinks, juices, water, or coffee and tea) that were consumed in the absence of food. If 2 eating occasions occurred in ≤ 15 min, both events were counted as a single eating occasion. When > 15 min separated 2 eating occasions, those occasions were considered distinct eating occasions. This method of calculating the number of eating occasions was described previously [23-26].

Appetite ratings

Before, immediately after and every 30 min for a period of 3h after the standardized breakfast, participants were asked to fill in 150-mm visual analogue scales (VAS) adapted from Hill and Blundell [27]. The measurements before breakfast were considered as the fasting measurement, and appetite ratings in response to the breakfast were evaluated by calculating the post-meal area under the curve (AUC) with the trapezoid method as previously described [28]. Appetite rating responses at 0, 30, 60, 90, 120, 150, and 180 min were considered in the calculation of the AUC.

Attitude toward eating

Eating behaviours were evaluated using the Three-Factor Eating Questionnaire (TFEQ) [29]. A French version of the 51-item TFEQ was administered to our subjects [30]. This questionnaire evaluates ‘dietary restraint’, which is a conscious control of food intake to control body weight or to promote weight loss; ‘disinhibition’, which is characterized by an overconsumption of foods in response to a variety of stimuli (e.g. emotional stress) associated with a loss of control on food intake; and ‘susceptibility to hunger’, which represents food intake in response to feelings and perceptions of physiological symptoms that signal the need for food. In addition, more specific subscales for these three general eating behaviours have been proposed by Westenhoefer et al. [31] and Bond et al. [32]. In the present study, we used the score of the two subscales of the TFEQ ‘dietary restraint’ behaviour: ‘rigid dietary restraint’ (dichotomous, all-or-nothing approach to eating, dieting and weight control) and ‘flexible dietary restraint’ (gradual approach to eating, dieting and weight control). The TFEQ has been shown to have good test-retest reliability and validity [29, 33].

Statistical analysis

SPSS was used for all analyses (version 17.0; SPSS Inc, Chicago, IL, USA). Differences between women who had successfully maintained a weight loss and never obese control women were compared using analysis of covariance (ANCOVA) controlling for age. Data are presented as means ± SD. All effects were considered significant at $P \leq 0.05$.

RESULTS

Characteristics of the participants

We studied a total of 44 subjects: 22 weight-loss maintainers and 22 never obese control women. As shown in **Table 1**, women in both groups were very closely matched when considering body weight and composition. As expected, weight-loss maintainers did not differ from never obese control women when body composition variables were compared. Women in the never obese control group were older than those in the weight-loss maintenance group. Consequently, analyses were controlled for age. The mean weight loss in the weight-loss maintenance group was 19.4 ± 8.6 kg (8.3-34.8 kg) (42.7 lbs; 18.3-76.6 lbs), which correspond to 22.5 ± 7.8 % (9.6-38.0 %) of their initial weight, and they maintained it for 2.8 ± 2.1 years (1-10 years) on average.

Energy expenditure

PAEE and TEE were significantly higher in the weight-loss maintenance group as compared to the never obese control group (**Figure 1**). The weight-loss maintenance group expended 180 kcal more per day in physical activity (1004.9 ± 248.6 kcal vs. 824.9 ± 255.2 kcal; $P < 0.05$) and had a higher EE throughout the day of 293 kcal (2639.5 ± 368.2 kcal vs. 2346.5 ± 349.4 kcal; $P < 0.05$) as compared with never obese control women. No significant group differences were observed for REE and TEF.

Time spent in physical activity of varying intensities

We observed that weight-loss maintainers spent significantly more minutes per week engaged in vigorous-intensity physical activity [> 6 metabolic equivalents (METs)] than did never obese control women (93.1 ± 73.1 min/week vs. 42.1 ± 46.2 min/week; $P < 0.05$) (**Figure 2**). No significant group differences were noted between weight-loss maintainers and never obese control women for the time spent per week doing sedentary (1-1.5 METs), light (1.5-3 METs), or moderate (3-6 METs) intensity physical activity.

Dietary intake and EF

No significant group difference for EI measured with the 7-day food diary (**Table 2**). Women in the weight-loss maintenance group ate less carbohydrate ($P < 0.05$) and had a higher protein intake expressed as percentage of total energy intake ($P < 0.05$) than women in the never obese control group (**Table 2**). The weight-loss maintainers ate approximately 4% more protein than never obese control women. The weight-loss maintenance group also had more frequent eating episodes than the never obese controls ($P < 0.01$) (**Table 2**).

Dietary intake at the buffet meal

Women in the weight-loss maintenance group had a higher spontaneous relative protein intake than women in the never obese control group (**Table 3**).

Appetite

No significant group differences were observed for all appetite variables (fasting and AUC desire to eat, hunger, fullness, and prospective food consumption) (**Table 4**). Although appetite values all appeared to be higher in the weight-loss maintenance group, these differences were not significantly different than that observed in the never obese controls.

Attitude toward eating

No significant group differences were observed for any of the three factors (dietary restraint, disinhibition and susceptibility to hunger) measured with the TFEQ. However, analyses of the subscales of the dietary restraint factor (rigid and flexible dietary restraint), revealed that weight-loss maintainers had a significantly higher level of rigid dietary restraint ($P < 0.05$) **(Table 5)**.

DISCUSSION

To our knowledge, this study is one of the first to compare energy balance (EE, EI, appetite and eating behaviours) variables using objective measures in women with no history of obesity and in successful weight-loss maintainers. Findings from this study suggest that successful weight-loss maintainers had higher PAEE and TEE; spent more time doing vigorous-intensity physical activity; had higher EF and percent protein intake; had lower carbohydrate intake (g); and had higher rigid dietary restraint compared with the never obese control group. Our data support previous findings that suggest both dietary intake and physical activity are key components to successful long-term weight-loss maintenance [3, 34].

Energy expenditure

One common characteristic among successful weight-loss maintainers is their participation in regular physical activity [35]. Past research has shown that increased physical activity, particularly high intensity activities, is associated with better weight-loss maintenance [3, 6-8, 36-38]. Results from the present study provide further evidence that high levels of physical activity are important for long-term weight-loss maintenance. These results show that weight-loss maintainers spent significantly more calories per day in physical activity than never obese control women. In addition to changes in PAEE, we also observed changes in time spent in various intensities of physical activity. Although the two groups performed a comparable amount of minutes of sedentary, light- and moderate-intensity physical activity, women in the weight-loss maintainers group spent significantly more time in vigorous-intensity physical activity than the never obese controls. These results are consistent with the findings of other studies [3, 6-8], which reported high levels physical activity in weight loss maintainers [3-4, 7]. On average, subjects who have succeeded in long-term weight-loss maintenance reported expending 2800 kcal/wk in physical activity [3, 7]. One study conducted by Phelan *et al.*, which compared 135 weight-loss maintainers to 102 always-normal-weight women, showed that weight-loss maintainers spent significantly more calories per day than the always-normal-weight women in physical activity, largely because of more time spent in higher-intensity activities [8]. The individuals in the weight-loss maintainers group spent about 8 min per day more in high-intensity physical activity than the always-normal-weight group, which is similar to ours results (7 min per day). Moreover, Cantenacci *et al.* also found that weight-loss maintainers spent significantly more time per day in moderate-to-vigorous physical activity than overweight and obese individuals and tend to engage in more structured physical activity as compared with never been obese controls [6]. These findings suggest that structured exercise may play a role in successful weight-loss maintenance. Our findings support current recommendations that more physical activity may be needed to prevent weight regain than to prevent weight gain [39].

One possible explanation to why greater duration of physical activity may be needed for weight regain prevention than for weight gain prevention is that subjects who are currently normal weight but have reduced from a prior period of being overweight or obese may experience metabolic alterations, and may thus require more effort to maintain body weight [40]. An increase in physical activity may serve to compensate for the weight loss-induced reduction in TEE [41]. Indeed, it have been documented that weight loss is accompanied by a decrease in REE, which have been shown to be a determinant of weight regain [42-43]. In a meta-analysis conducted by Astrup *et al.*, it has been showed that formerly obese subjects had a 3-5% lower mean relative resting metabolic rate (RMR) than never obese control subjects [44]. This difference could be explained by a low RMR being more frequent among the reduced-obese subjects than among the never obese control subjects [44]. In the present study, we did not observe any difference in REE between groups. These results are consistent with results reported in other studies that showed that REE in reduced-obese subjects was not significantly different from that in normal body weight subjects [45]. Possible reasons for this finding include that high levels of physical activity observed in the present study may have masked a lower REE [4]. Van Dale *et al.* reported that individuals who exercise regularly during and following weight loss had a "normal" REE relative to body mass, whereas non-exercising subjects had a lower-than predicted REE relative to body mass [46].

Dietary intake and EF

Findings from the NWCR suggest that individuals who succeed at long-term weight-loss maintenance consume low-energy, low-fat diets [5]. Previous studies have also suggested that successful weight-loss maintainers consumed significantly less fat than never obese women [12]. In the present study, although daily caloric and fat intakes seem to be lower in the weight-loss maintenance group as compared with never obese control women, we did not find any significant group difference. Research also indicates that an increase in protein intake at the expense of other macronutrients (fat and carbohydrate) may promote satiety and facilitate weight loss and weight-loss maintenance [47-48]. In a study of 113 overweight and obese subjects who lost 5-10% of their body weight during a 4-week very-low-energy diet, Lejeune et al. observed that those who consumed 18% of their energy intake as protein during a 6-month weight management period regained less weight than subjects who consumed 15% of their energy intake as protein [49]. Results from the present study provide further evidence that higher protein intake could be important body weight management. Indeed, we found that women in the weight-loss maintenance group had higher percent protein intake than women in the never obese control group. Weight-loss maintainers tended also to have a higher consumption of protein in grams, but this difference did not reach statistical significance. These findings suggest that an increase in protein intake may offer a way to increase satiety and to have a better control on EI, which can enhance weight-loss maintenance.

Little is known about the relation between EF and weight-loss maintenance. Only two studies have investigated this issue [3, 50]. Both studies found that successful weight-loss maintainers had approximately five eating occasions per day, which is similar to our results. In a cross-sectional study of 257 individuals, Bachman et al. compared EF between successful weight-loss maintainers, normal weight, and overweight individuals [50]. They found that weight-loss maintainers and normal weight individuals had more frequent daily eating occasions than overweight individuals. Opposite to Bachman's study, we found a difference in EF between weight-loss maintainers and never obese control women. Women in the weight-loss maintenance group had a higher EF than women in the never obese control group. The higher EF observed in the weight-loss maintenance group could be explained by a higher level of physical activity. Indeed, in a previous study, we have shown that physical activity is a confounding factor of the relation between EF and body composition [26]. However, the group difference for EF was still significant after adjustment for PAEE.

In the present study, the difference between EI and EE was abnormally high for each group (weight-loss maintainers = -727 kcal/day; never obese = -249 kcal/day) whereas women was in weight stability (± 2 kg) for 6 months or more before enrolment in the study. One possible explanation for this finding is related with under-reporting. Indeed, without underreporters, the difference between EI and EE was -240 kcal/day for the weight-loss maintenance group and -130 kcal/day for the never obese group. When asked, people in general tend to under-estimate the amount of food they eat. Every self-report modality is prone to the problem of underreporting. The problem of dietary underreporting has been addressed in a number of articles as a major limitation in dietary assessments and it is not easily overcome [51-53]. Underreporting can range widely from 10 to 91% depending on the population, method, definition and cut-points used to categorize underreporters [54-56]. The proportion of underreporting in the present study was ≅ 52% (≅ 27% in the never obese group and ≅ 77% in the weight-loss maintenance group). Underreporting was assessed by direct comparison of recorded EI and measured EE. The ratio between EI and TEE was determined for each subject. Participants with a ratio of reported EI to EE < 0.74 were classified as underreporters [57-58]. The higher percentage of underreporting in the weight-loss maintainers group was not surprising, considering that history of dieting and being overweight or obese were associated with underreporting of EI [54-55, 59-63]. After removing underreporters from statistical analyses for dietary intake from 7-day food diary, the group differences observed were no longer significant. The small sample size in the weight-loss maintenance group (n=5) after removing underreporters may have affected our ability to observe difference between groups.

Appetite

In the present study, although the weight-loss maintainers tended to present higher appetite values these differences were not significant. The absence of significant difference in appetite level between weight-loss maintainers and never obese control women could possibly be explained by the higher consumption of protein, with the same EI, in the weight-loss maintenance group, which can offset the increase in appetite that can be observed after weight-loss [64-65]. Indeed, it was shown that weight loss causes a decrease in leptin and an increase in ghrelin, which could results in an increase in appetite [66]. In a longitudinal study of 50 overweight and obese subjects enrolled in a 10-week weight-loss program, Sumithran et al. have shown that weight-loss led to significant changes in levels of appetite-regulating hormones appetite that promote weight regain, as well as changes in appetite [67]. These changes persist for at least 1 year after weight-loss.

Attitude toward eating

It was shown that high levels of dietary restraint are associated with better weight-loss maintenance [3, 68-70]. Indeed, in a cross-sectional study of 303 individuals, Phelan et al. found that weight-loss maintainers had a higher dietary restraint than always-normal weight individuals [12]. In the present study, no significant difference in dietary restraint was observed between groups, but we found that weight-loss maintainers had higher rigid dietary restraint than never obese control women. Given that rigid dietary restraint has been associated with higher BMI, this finding could be surprising [71-72]. However, higher rigid dietary restraint observed in weight-loss maintainers could be explained by their history of dieting. Indeed, it was shown that current and past dieters had higher rigid dietary restraint compared with non-dieters [73]. As compared with never obese women, a higher rigid dietary restraint eating pattern may enable weight-loss maintainers to have an energy-controlled diet and to compensate for the increase in appetite that can be observed after weight loss.

This study presents some limitations. First, the small sample size and the healthy homogenous population limit the external validity of our results and may have affected our ability to observe difference between groups for some variables of interest. This is a pilot study, so future studies are needed to extend the findings observed in this study. Second, the cross-sectional design limits the conclusions that can be drawn about the causal relation between weight-loss maintenance and the energy balance variables measured in this study. Nonetheless, this study examined both side of the energy balance, which may give a better portrait of how weight is being regulated in the weight-loss maintainers and never obese women. Finally, gold standard measure (DXA) for body composition and objective measures of EE, dietary intake and appetite were used.

CONCLUSION

In summary, weight-loss maintainers spent more calories per day in physical activity, engaged in more minutes of vigorous-intensity physical activities, ate more frequently, consumed more protein and less carbohydrate, and had a higher rigid dietary restraint compared with their never obese control counterparts. The present study suggests that, taken together, an increase in satiating macronutrients in association with an increase in physical activity and an energy-controlled diet may improve weight-loss maintenance.

ACKNOWLEDGEMENTS

The authors would like to thank the participants for their devoted participation and to the staff of Behavioural and Metabolic Research Unit (BMRU) for their contribution to this study. This study was supported by CNFS (Consortium National de Formation en Santé) and CIHR (Canadian Institute for Health Research) grants: 63279 MONET study (Montreal Ottawa New Emerging Team). K Duval is a recipient of the FRSQ (Fonds de la Recherche en Santé du Québec) Doctoral support program. R Rabasa-Lhoret is a recipient of the FRSQ clinical researcher scholarship and holds the J-A DeSève chair.

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Table 1. Subjects characteristics.

Variables	Weight-loss maintenance group (n=22)	Never obese control group (n=22)	Effect
Age (years)	35.9 ± 8.8 (23-50)	49.6 ± 1.6 (47-54)	< 0.01
Body weight (kg)	65.3 ± 9.2 (50.7-79.6)	65.0 ± 8.9 (49.9-79.7)	NS
BMI (kg/m²)	24.3 ± 3.2 (17.8-30.7)	23.5 ± 2.7 (19.3-28.1)	NS
Fat mass (kg)	20.0 ± 7.4 (8.8-33.0)	19.9 ± 6.6 (9.8-31.6)	NS
Fat-free mass (kg)	44.6 ± 5.0 (34.1-54.6)	44.8 ± 4.8 (35.3-52.2)	NS
% Body fat	30.3 ± 8.1 (16.5-43.1)	30.2 ± 6.9 (18.2-40.7)	NS

NS: Not significant; BMI: Body Mass Index. Values are mean ± SD (all such values).

Table 2. Comparison of dietary intake and EF from the 7-day food diary by subject group.

Variables	Weight-loss maintenance group (n=22)	Never obese control group (n=22)	Effect
EI (kcal/day)	1912.7 ± 373.0	2097.7 ± 486.9	NS
Protein (%)	19.0 ± 3.4	15.4 ± 2.7	$P < 0.05$
Carbohydrate (%)	49.4 ± 7.4	51.7 ± 7.0	NS
Fat (%)	29.9 ± 7.3	32.5 ± 4.7	NS
Protein (g)	92.1 ± 22.3	80.5 ± 22.4	NS
Carbohydrate (g)	243.8 ± 72.2	272.5 ± 77.2	$P < 0.05$
Fat (g)	64.2 ± 17.1	75.9 ± 22.1	NS
Dietary fiber (g)	27.8 ± 14.5	23.5 ± 10.5	NS
EF (eating occasions/day)	5.4 ± 0.7	4.4 ± 0.9	$P < 0.01$

ANCOVA controlling for age. NS: Not significant; EI: energy intake; EF: eating frequency. Values are mean ± SD.

Table 3. Comparison of dietary intake during the buffet by subject group.

Variables	Weight-loss maintenance group (n=22)	Never obese control group (n=22)	Effect
EI (kcal)	443.1 ± 214.7	630.6 ± 263.2	NS
Protein (%)	20.0 ± 8.3	19.2 ± 6.5	$P < 0.05$
Carbohydrate (%)	53.2 ± 14.7	49.2 ± 12.3	NS
Fat (%)	26.8 ± 11.5	33.3 ± 11.5	NS
Protein (g)	22.1 ± 11.1	30.2 ± 15.6	NS
Carbohydrate (g)	59.0 ± 31.9	75.2 ± 34.9	NS
Fat (g)	14.2 ± 10.5	24.1 ± 14.2	NS

ANCOVA controlling for age. NS: Not significant; EI: energy intake. Values are mean ± SD.

Table 4. Comparison of appetite variables by subject group.

Appetite variables	Weight-loss maintenance group (n=22)	Never obese control group (n=22)	Effect
Fasting desire to eat (mm)	97.3 ± 31.5	83.4 ± 44.5	NS
Fasting hunger (mm)	97.1 ± 40.7	71.4 ± 41.2	NS
Fasting fullness (mm)	22.3 ± 25.7	29.1 ± 32.7	NS
Fasting PFC (mm)	93.9 ± 26.2	80.4 ± 36.1	NS
AUC desire to eat (mm x min)	5452.5 ± 3851.4	6021.5 ± 3504.6	NS
AUC hunger (mm x min)	5435.8 ± 3467.2	6546.4 ± 3811.2	NS
AUC fullness (mm x min)	17 863.6 ± 5071.0	17 436.5 ± 4371.0	NS
AUC PFC (mm x min)	6150.7 ± 3271.9	7553.9 ± 4170.3	NS

ANCOVA controlling for age. NS: Not significant; PFC: prospective food consumption; AUC: area under the curve. Values are mean ± SD.

Table 5. Comparison of TFEQ variables by subject group.

TFEQ variables	Weight-loss maintenance group (n=22)	Never obese control group (n=22)	Effect
Dietary restraint	11.4 ± 3.0	9.8 ± 3.4	NS
Disinhibition	5.6 ± 2.1	4.4 ± 2.3	NS
Hunger	6.0 ± 3.1	4.7 ± 3.5	NS
Rigid dietary restraint	2.5 ± 1.2	1.4 ± 1.3	$P < 0.05$
Flexible dietary restraint	2.4 ± 0.9	2.2 ± 1.0	NS

ANCOVA controlling for age. NS: Not significant. Values are mean ± SD.

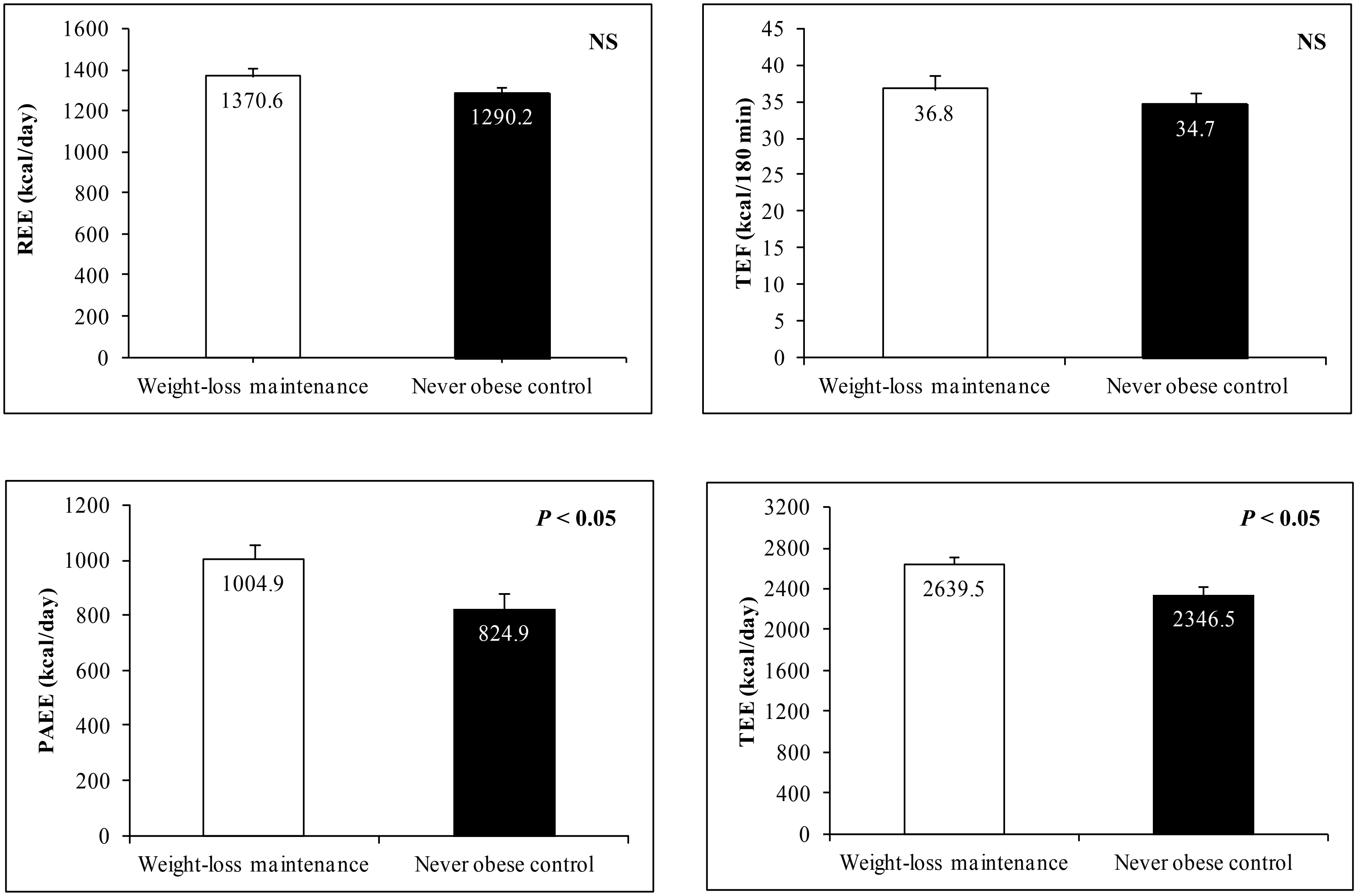

Figure 1. Comparison of energy expenditure by subject group. ANCOVA controlling for age. REE: resting energy expenditure; TEF: thermic effect of food; PAEE: physical activity energy expenditure; TEE: total energy expenditure; NS: not significant. Values are mean ± SEM.

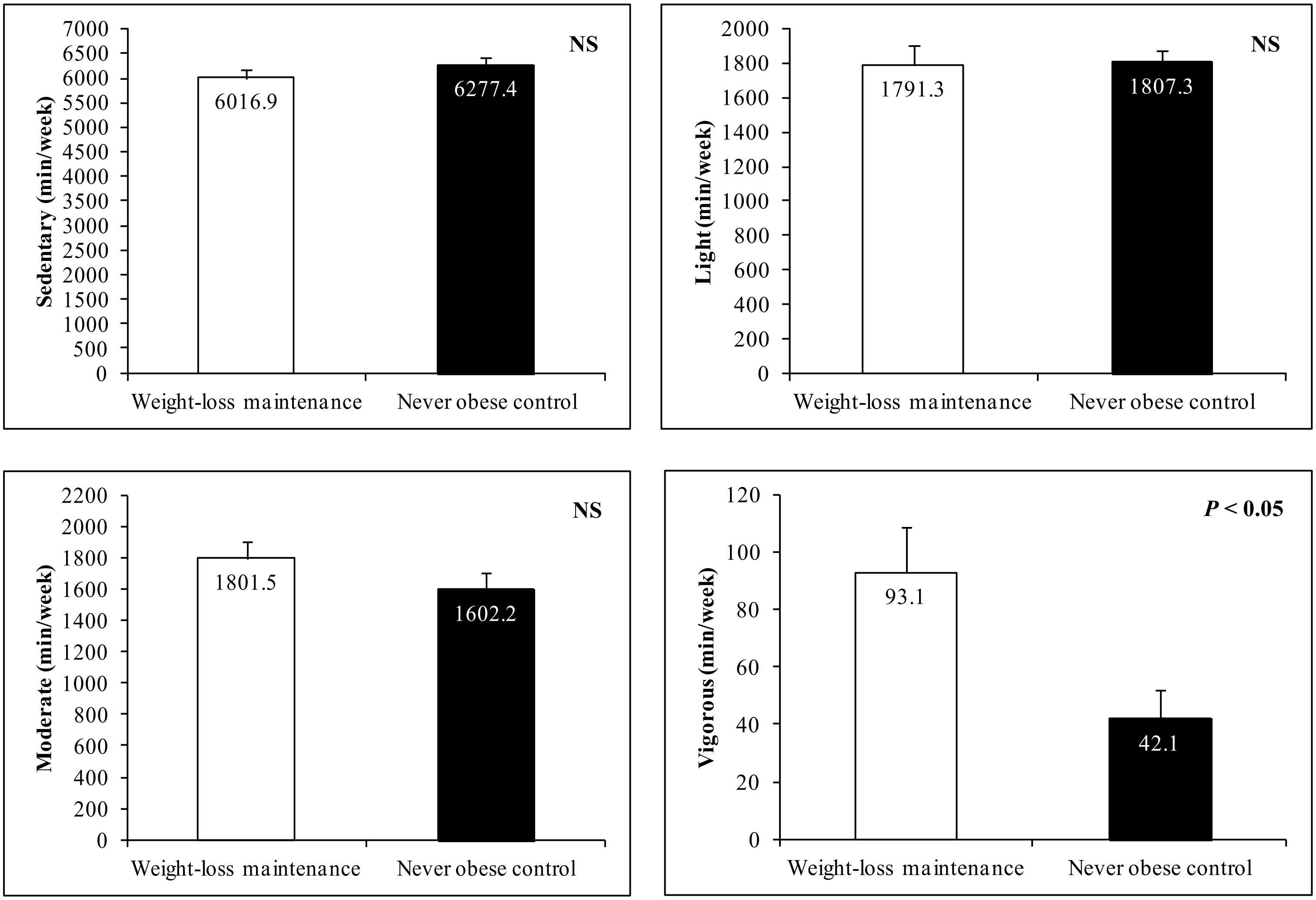

Figure 2. Comparison of time spent in physical activity intensities by subject group. ANCOVA controlling for age. Sedentary physical activity [1-1.5 metabolic equivalents (METs)], light-intensity physical activity (1.5-3 METs), moderate-intensity physical activity (3-6 METs), vigorous-intensity physical activity (> 6 METs). NS: not significant. Values are mean ± SEM.

CHAPITRE 4

L'ACTIVITÉ PHYSIQUE EST UN FACTEUR CONFONDANT DE LA RELATION ENTRE LA FRÉQUENCE DES REPAS ET LA COMPOSITION CORPORELLE CHEZ LES FEMMES PRÉMÉNOPAUSÉES.

Karine Duval, Irene Strychar, Marie-Josée Cyr, Denis Prud'homme, Rémi Rabasa-Lhoret, Éric Doucet

L'article composant ce chapitre est intitulé :

«Physical activity is a confounding factor of the relation between eating frequency and body composition.»

(*American Journal of Clinical Nutrition* 2008; 88: 1200-1205)

Contribution des auteurs :

Irene Strychar, Denis Prud'homme, Rémi Rabasa-Lhoret et Éric Doucet ont participé à l'élaboration de ce projet de recherche (MONET). Karine Duval et Marie-Josée Cyr ont participé à la collecte des données. Karine Duval a effectué l'analyse et l'interprétation des données ainsi que la rédaction du manuscrit. Tous les auteurs ont participé à la révision du manuscrit.

RÉSUMÉ

Contexte : Il a été observé que la fréquence des repas peut être associée à la composition corporelle chez la femme, cependant les résultats demeurent controversés. Ces résultats divergents pourraient être expliqués par la contribution potentielle de facteurs confondants tels que la pratique d'activité physique.

Objectifs : Les objectifs de cette étude étaient de mesurer la relation entre la fréquence des repas et la composition corporelle chez les femmes préménopausées et d'explorer l'effet de la pratique d'activité physique et de la condition cardio-respiratoire sur cette association.

Méthodes : Quatre-vingt-cinq femmes préménopausées (âge : 49,9 ± 2,0 ans ; IMC : 23,2 ± 2,2 kg/m²) ont été étudiées au début d'une étude observationnelle prospective. Un journal alimentaire de 7 jours a été utilisé pour mesurer l'apport alimentaire et la fréquence des repas. La composition corporelle (mesurée par ostéodensitométrie à absorptiométrie bi-photonique), la condition cardio-respiratoire (mesurée par la consommation maximale d'oxygène) et la dépense énergétique associée à l'activité physique (mesurée par accélérométrie) ont également été mesurées.

Résultats : La fréquence des repas moyenne était de 4,6 ± 0,9 occasions de manger / jour. Une corrélation significative positive entre la fréquence des repas et l'apport calorique a été notée ($r = 0,31$, $P < 0,01$). De plus, il a été observé que la fréquence des repas était négativement corrélée avec l'indice de masse corporelle ($r = -0,25$, $P < 0,05$), le tour de taille ($r = -0,32$, $P < 0,01$), le pourcentage de graisse corporelle ($r = -0,26$, $P < 0,05$) et la masse adipeuse ($r = -0,27$, $P < 0,05$). Les associations entre les mesures d'adiposité et la fréquence des repas n'étaient plus significatives après correction pour la dépense énergétique associée à l'activité physique et la condition cardio-respiratoire.

Conclusion : La relation entre la fréquence des repas et la composition corporelle pourrait être influencée par la pratique d'activité physique et la condition cardio-respiratoire chez les femmes préménopausées.

Original Research Communications

Physical activity is a confounding factor of the relation between eating frequency and body composition[1–3]

Karine Duval, Irene Strychar, Marie-Josée Cyr, Denis Prud'homme, Rémi Rabasa-Lhoret, and Éric Doucet

ABSTRACT

Background: It has been shown that eating frequency (EF) is related to body composition in women, but the results are inconclusive. These inconsistent findings could be due to the influence of additional factors such as physical activity.

Objective: We aimed to investigate the relation between EF and body composition in premenopausal women and to explore the effect of physical activity energy expenditure (PAEE) and physical fitness on that association.

Design: Eighty-five premenopausal women [$\bar{x}$ ± SD age: 49.9 ± 2.0 y; body mass index (in kg/m^2): 23.2 ± 2.2] were studied at the onset of a prospective observational study. Seven-day food diaries were used to measure energy intake and EF. Body composition (measured with dual-energy X-ray absorptiometry), physical fitness (measured by the peak oxygen consumption), and PAEE (measured by using an accelerometer) were also measured.

Results: Mean EF was 4.6 ± 0.9 eating occasions/d. A significant positive correlation was found between EF and energy intake (r = 0.31, $P < 0.01$). Moreover, EF was negatively correlated with body mass index ($r = -0.25$, $P < 0.05$), waist circumference ($r = -0.32$, $P < 0.01$), percentage body fat ($r = -0.26$, $P < 0.05$), and fat mass ($r = -0.27$, $P < 0.05$). The associations between adiposity and EF were no longer significant after correction for PAEE and peak oxygen consumption.

Conclusion: The relation between EF and body composition could be mediated by PAEE and physical fitness. *Am J Clin Nutr* 2008;88:1200–5.

INTRODUCTION

It has been reported that reduced eating frequency (EF) could contribute to the development of obesity (1) and that higher EF is associated with better body-weight control (2). Fabry et al (3, 4) were the first investigators to show an inverse association between EF and body weight. Many epidemiologic and clinical studies subsequently explored the association between EF and body weight, but results have been inconsistent. Some studies observed an inverse relation between EF and body weight (5–9), whereas others failed to detect any significant association (10–12). Drummond et al (13) showed that eating more frequently is related to leanness in men but not in women. In women, although a positive correlation between EF and energy intake (EI) was observed, no relation was found between body weight and EF (13, 14). The inconsistent results pertaining to the relation between EF and adiposity in women should be explored further to allow consideration also of the contribution of potential confounders such as physical activity energy expenditure (PAEE).

Most studies of EF and energy metabolism have failed to show any influence of EF on energy expenditure (EE) (15–19). It was also found that higher EF has no effect on resting EE (REE) (18), and the studies of the thermic effect of food were inconclusive (20–22). Few of the published studies of EF and body weight have included a measure of the subjects' daily physical activity (13, 14). In those studies, self-reported questionnaires and physical activity diaries were used to assess daily physical activity. A positive correlation between EF and EE during leisure time (13) and at home (14) was found in women, which suggests that women who ate more frequently had greater EE from physical activity. This correlation could partly explain the absence of a relation between EF and body composition in women, despite a higher EI. Little information relating EF to PAEE and body composition is available.

The relation between EF and adiposity remains unclear. To our knowledge, no study has investigated the effect of EF on body composition in premenopausal women by using a direct measurement of PAEE and physical fitness. Hence, the present study was performed to investigate the relation between EF and body composition in premenopausal women and to further explore the effect of PAEE and physical fitness on this relation.

SUBJECTS AND METHODS

Subjects

Eighty-five premenopausal women were evaluated for a prospective observational study. Volunteers were recruited through

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[2] Supported by a grant from Canadian Institute of Health Research (CIHR) # OHN – 63279. Éric Doucet is a recipient of a CIHR/Merck-Frosst New Investigator Award, a CFI/OIT New Opportunities Award and an Early Research Award (Ontario). Karine Duval is a recipient of the FRSQ (Fonds de la recherche en Santé du Québec) Doctoral support program. Rémi Rabasa-Lhoret is a Scholar (Junior II) of the FRSQ.

[3] Reprints not available.

Received March 28, 2008. Accepted for publication June 26, 2008.
doi: 10.3945/ajcn.2008.26220.

newspaper advertisements and information sessions. All participants took part in a screening session to ensure that they met the following inclusion criteria: *1*) premenopausal women between 48–55 y old; *2*) regular menstrual cycle; *3*) nonsmoker; *4*) body mass index (BMI; in kg/m^2) between 20 and 29; *5*) weight stability ($\pm$2 kg) for $\geq$6 mo before enrollment in the study; *6*) no known disease or disability; and *7*) no current medications that could influence food intake or metabolism.

Written informed consent was obtained from each participant. The study received approval from the University of Ottawa and Montfort Hospital ethics committees.

Anthropometric measurements

Body weight and height were measured with a BWB-800AS digital scale and a Tanita HR-100 height rod (Tanita Corporation of America, Inc, Arlington Heights, IL), respectively, while participants were wearing a hospital gown and no shoes. Waist circumference was measured with a conventional measuring tape at the midpoint between the last floating rib and the upper part of the iliac crest. An average of 2 measurements was taken. Body composition was measured by using dual-energy X-ray absorptiometry (DXA; GE-LUNAR Prodigy module; GE Medical Systems, Madison, WI.). CVs and correlation for percentage body fat (%BF) measured in 12 healthy subjects tested in our laboratory were 1.8% and r = 0.99, respectively.

Dietary assessment

EI and macronutrient intake were assessed with the use of a 7-d food diary. Subjects were asked to record the type and amount of foods and beverages consumed for 7 consecutive days. The time and place of eating of food were recorded as well. Participants received oral and written instructions on recording their food intake. They were asked to be as specific as possible in their description by indicating all main ingredients and the quantity, the brand of products, and the cooking method. Participants were also asked to bring food labels, when possible, to facilitate the analysis of the food diary. Recorded data were carefully verified on the return of the food diary to obtain forgotten data or to correct misreported data. The food diaries were analyzed by a registered dietitian with the use of FOOD PROCESSOR SQL software (version 9.6.2; ESHA Research, Salem, OR).

Establishing the number of eating occasions

Data from the food diaries were also used to calculate the average number of eating occasions per day, ie, EF. Eating occasions were defined as any occasion when food was consumed (13). The definition excluded drinks (alcoholic drinks, soft drinks, juices, water, or coffee and tea) that were consumed in the absence of food. If 2 eating occasions occurred in $\leq$15 min, both events were counted as a single eating occasion. When >15 min separated 2 eating occasions, those occasions were considered distinct eating occasions. This method of calculating the number of eating occasions was described previously (13, 14, 23). Details concerning EF, the caloric and macronutrient intake for meals, and the snacks and drinks (consumed without food) are provided in **Appendix A**.

Assessment of underreporting

Underreporting was assessed by direct comparison of recorded EI and measured EE. The ratio between EI and TEE was determined for each subject. Total EE (TEE) was calculated by using the following formula:

$$\text{TEE} = (\text{PAEE} + \text{REE}) \times 1.11 \qquad (1)$$

where the thermic effect of food was fixed at 10% of TEE. Participants with a ratio of <0.74 were classified as underreporters (24, 25). PAEE was assessed by using 7-d accelerometry, and REE was measured by indirect calorimetry (Deltatrac II metabolic cart; SensorMedics Corporation, Yorba Linda, CA). REE was measured for 30 min after a 12-h overnight fast. The first and last 5 min were excluded from the calculations, and thus minutes 6–25 were used in the calculation. Mean REE was calculated by using the equation of Weir (26). CV and correlation for the determination of REE with the Deltatrac II metabolic cart in our laboratory was 2.3% and r = 0.98, respectively, as determined in 12 healthy subjects.

Assessment of physical activity energy expenditure

Assessment of PAEE was performed by using biaxial accelerometry units (Actical; Mini Mitter Co, Inc, Bend, OR), which have been shown to be reliable (27). The accelerometer was used to estimate mean daily EE from physical activity. Participants put on the accelerometer upon waking up and took it off just before going to bed. Accelerometry and dietary data were collected simultaneously for 7 d. Such a duration was chosen because it is estimated to result in 90% reliability for the measurement of physical activity in both males and females (28). The accelerometer was worn at the lower back, because that placement, when evaluated along with lower leg or foot, upper leg, head and trunk, lower arm or hand, and upper arm placements, was the best predictor of EE (r = 0.92–0.97) (29). The accelerometers used in this study were validated previously with the use of doubly labeled water measurements (30).

Maximal aerobic capacity

A maximal aerobic capacity ($\dot{V}O_{2max}$) (31) test was performed to determine maximal oxygen uptake of the participants. Participants were asked to refrain from any vigorous exercise and consumption of alcoholic beverages for the 6 h before the test and to abstain from eating and drinking coffee for 2 h before the fitness test. The test consisted of 3-min stages (progressing from walking to running) on a treadmill with an increasing workload to the point of exhaustion. Breath-by-breath samples of expired air were collected through a mouthpiece throughout the test, and measurements of $\dot{V}O_2$ and the respiratory exchange ratio were made automatically by using a Vmax 229 series metabolic cart (SensorMedics Corporation). The indirect calorimetry unit was calibrated according to the manufacturer's specifications before every test to further ensure the reliability of the data collected. After a brief warm-up, subjects performed the test protocol; the assessment was terminated when $\geq$2 of the following criteria were achieved: *1*) predicted maximal heart rate was reached; *2*) respiratory quotient was >1.1; *3*) oxygen consumption remained stable or decreased with an increase in workload; and *4*) the rate of perceived exertion measured with the Borg scale reached 19 or 20 (32). Because a plateau of $\dot{V}O_2$ was not achieved in most subjects, peak oxygen consumption ($\dot{V}O_{2peak}$) will be used henceforth to describe the results.

Statistical analysis

Statistical analyses were performed with the use of SPSS software (version 11.5; SPSS Inc, Chicago, IL). Relations between EF and body composition, EI, macronutrient composition, PAEE, and $\dot{V}O_{2peak}$ were investigated by using Pearson correlation coefficients (one-tailed). Associations between EF and body composition, EI, and macronutrient composition were further explored by using partial correlations after control for PAEE and $\dot{V}O_{2peak}$ (one-tailed). All effects were considered significant at $P < 0.05$. Data are presented as means ± SDs.

RESULTS

Low energy reporters

As described in Methods, low energy reporters were identified and excluded from the analyses. Records from 16 subjects had ratios of EI to TEE (EI:TEE) below the cutoff of 0.74, and those subjects were identified as underreporters. The underreporters represented 18.8% of the study population. Data from a total of 69 premenopausal women, whose characteristics are presented in **Table 1**, were thus included in the final analyses. The underreporters, as compared with valid reporters, had significantly higher body weight (64.6 ± 5.4 and 59.8 ± 6.9 kg, respectively; $P < 0.05$), BMI (24.4 ± 2.4 and 23.0 ± 2.2, respectively; $P < 0.05$), waist circumference (81.7 ± 5.8 and 77.2 ± 6.8 cm, respectively; $P < 0.05$), %BF (34.3 ± 5.2% and 30.4 ± 6.7%, respectively; $P < 0.05$), and fat mass (22.1 ± 4.2 and 18.3 ± 5.4 kg, respectively; $P < 0.01$). With regard to their dietary intake, underreporters, as compared with valid reporters, had significantly lower EI (1684.5 ± 333.9 and 2069.8 ± 369.6 kcal, respectively; $P < 0.001$), carbohydrate intake (224.3 ± 51.7 and 262.6 ± 62.4 g, respectively; $P < 0.05$), protein intake (67.9 ± 14.8 and 80.6 ± 15.1 g, respectively; $P < 0.01$), and fat intake (57.9 ± 17.0 and 74.8 ± 19.1 g, respectively; $P < 0.01$).

TABLE 1
Characteristics of the premenopausal women[1]

Variable	Value
Age (y)	50.0 ± 2.0 (47–56)[2]
Body weight (kg)	59.8 ± 6.9 (46.8–79.7)
Height (m)	1.61 ± 0.07 (1.50–1.81)
Waist circumference (cm)	77.2 ± 6.8 (62.2–93.0)
BMI (in kg/m²)	23.0 ± 2.2 (19.3–28.5)
BMI distribution (%)	
<25 (*n* = 53)	76.8
25 < BMI < 30 (*n* = 16)	23.2
Percentage total body fat	30.4 ± 6.7 (18.2–41.7)
Percentage total body fat distribution (%)	
<35% (*n* = 50)	72.5
≥35% (*n* = 19)	27.5
Fat mass (kg)	18.3 ± 5.4 (9.6–31.6)
Fat-free mass (kg)	41.1 ± 4.4 (33.2–52.2)
$\dot{V}O_{2peak}$ (mL · kg^{-1} · min^{-1})	34.0 ± 6.0 (20.9–52.0)
PAEE (kcal/d)	747.4 ± 206.8 (326.3–1268.0)
REE (kcal/d)	1214.3 ± 109.0 (946.0–1460.0)
Energy intake (kcal/d)	2069.8 ± 369.6 (1436.8–2940.1)
Energy source	
Protein (% of energy)	15.4 ± 2.8 (9.0–22.3)
Carbohydrate (% of energy)	49.4 ± 6.5 (30.4–65.9)
Fat (% of energy)	31.5 ± 5.2 (19.7–42.7)
Alcohol (% of energy)	3.4 ± 3.2 (0.0–14.3)
Protein (g)	80.6 ± 15.1 (35.2–121.8)
Carbohydrate (g)	262.6 ± 62.4 (138.4–422.5)
Fat (g)	74.8 ± 19.1 (38.1–124.9)
Alcohol (g)	10.2 ± 9.2 (0.0–37.2)
Eating frequency (eating occasions/d)	4.6 ± 0.9 (3.0–7.1)

[1] *n* = 69. $\dot{V}O_{2peak,}$ peak oxygen uptake; PAEE, physical activity energy expenditure; REE, resting energy expenditure.
[2] $\bar{x}$ ± SD (all such values).

TABLE 2
Correlations of energy intake and macronutrient composition with eating frequency in premenopausal women[1]

	Eating frequency	
	r	*P*
Energy intake	0.31	0.005
Energy source		
Protein (% of energy)	0.02	0.44
Carbohydrate (% of energy)	0.21	0.045
Fat (% of energy)	−0.11	0.19
Alcohol (% of energy)	−0.17	0.08
Protein (g)	0.31	0.005
Carbohydrate (g)	0.37	0.001
Fat (g)	0.13	0.14
Alcohol (g)	−0.13	0.14

[1] *n* = 69. Values obtained with the use of Pearson's correlation coefficient.

Correlations between eating frequency and body composition

Mean EF was 4.6 ± 0.9 (range: 3.0–7.1) eating occasions/d. EF was negatively correlated with BMI ($r = -0.25$, $P < 0.05$), waist circumference ($r = -0.32$, $P < 0.01$), %BF ($r = -0.26$, $P < 0.05$), and fat mass ($r = -0.27$, $P < 0.05$). These findings suggest that women who ate more frequently also tended to have lower adiposity.

Correlations of eating frequency with energy intake and macronutrient composition

The correlation coefficients of EF with EI and macronutrient composition are shown in **Table 2**. A significant positive correlation was found between EF and EI, which suggests that women who ate more frequently also tended to have higher EIs. Significant positive correlations were also observed between EF and the percentage of energy from carbohydrates and between EF and carbohydrate and protein intakes expressed in grams.

Correlations of eating frequency with physical activity energy expenditure, resting energy expenditure, and peak oxygen consumption

Significant positive correlations were found between EF and PAEE ($r = 0.29$, $P < 0.01$) and between EF and $\dot{V}O_{2peak}$ ($r = 0.45$, $P < 0.001$). No significant correlation was noted for EF and REE.

Partial correlations of eating frequency with body composition, energy intake, and macronutrient composition

Partial correlations of EF with body composition, EI, and macronutrient composition were performed after control for PAEE and $\dot{V}O_{2peak}$. The results of these analyses (**Table 3**) show

TABLE 3
Partial correlations of body composition, energy intake, and macronutrient composition with eating frequency in premenopausal women[1]

	Eating frequency	
	r	*P*
BMI	−0.04	0.37
Waist circumference	−0.21	0.04
Percentage body fat	0.06	0.31
Fat mass	−0.02	0.43
Energy intake	0.11	0.19
Carbohydrate (g)	0.19	0.06
Carbohydrate (% of energy)	0.15	0.11
Protein (g)	0.21	0.04

[1] $n = 69$. Partial correlations after control for physical activity energy expenditure and peak oxygen uptake.

that the associations between adiposity and EF disappeared after correction for PAEE and $\dot{V}O_{2peak}$. Among adiposity variables, only the association between EF and waist circumference remained significant after correction. The significant relations between EF and EI also disappeared, whereas correlations remained significant between protein intake (in g) and EF.

DISCUSSION

EF has been shown to be related to body composition, but results are inconsistent (2). It was postulated that these inconsistent findings could be the result of the influence of additional factors, such as those that may affect TEE (13). The present study was thus performed to investigate the presence of a relation between EF and body composition in premenopausal women and to explore the effect of PAEE and $\dot{V}O_{2peak}$ on this association. We found that EF was positively associated with EI and negatively associated with adiposity. It is interesting that the associations between EF and adiposity disappeared after correction for PAEE and $\dot{V}O_{2peak}$. To our knowledge, the present study is the first to investigate the effect of EF on body composition in premenopausal women by using a direct assessment of PAEE and physical fitness.

Eating frequency and body composition

The results of the present study confirm previous findings on the relation between EF and body composition in women. Indeed, the inverse association found between body composition and EF in women is consistent with the findings of several other studies (5, 7, 8). However, in more recent studies by Drummond et al (13) and Yannakoulia et al (14), no such relation was found. The methodologic discrepancies that have been proposed to explain these contradictory results include underreporting of food intake, various definitions of eating occasions, various methods of assessing food intake and body composition, and the fact that many studies did not take into account factors related to EE (33). As in the studies by Drummond et al (13) and Yannakoulia et al (14), the present study took measures to ensure that underreporting did not bias the results. We screened the individual food diary results for underreporting by using validated procedures (25, 26), and we excluded all low energy reporters from the analyses. The proportion of underreporting in the present sample was ≈19%, which is similar to that in another recent study (13). This percentage was not surprising, considering that approximately one-third of our sample was considered obese according to %BF. Indeed, research evidence indicates that underreporting is habitually more frequent in overweight and obese persons (25, 32, 34). In support of that, we found that the underreporters had a higher BMI, %BF, and fat mass than did the valid reporters.

The type of definition used to describe eating occasions may significantly influence the outcomes and interpretation of the studies (33, 35). As did Drummond et al (13) and Yannakoulia et al (14), we opted for a widely used definition, in which 2 consecutive eating occasions were considered separate if they occurred >15 min apart. This definition was chosen to avoid the ambiguities of classifying eating events as either "meals" or "snacks," which can mask the number of actual eating occasions, especially when EF is high (33). Unlike the definition used in the present study, the eating occasion definition used by Yannakoulia et al (14) included all drinks consumed in the absence of food, which may have led to higher EF than was seen in present study (5.9 and 4.6/d, respectively). In the present study, we found a mean EF of 4.6 ± 0.9 eating occasions/d (range: 3.0–7.1 eating occasions/d). The studies that used EF as the definition of eating occasions also found little variation in EF among the women. Drummond et al (13) had a mean EF of 4.4 ± 1.1 eating occasions/d (range: 2.7–9.0 eating occasions/d), and Yannakoulia et al (14) had a mean EF of 5.9 ± 1.4 eating occasions/d (range: 2.7–10.0 eating occasions/d).

The method used to assess food intake is worth taking into account when measuring EF. Various methods have been used in EF studies, but results do not differ consistently according to the method of assessment. Indeed, Metzner et al (5) (24-h dietary recall) and Burley et al (8) (4-d food diary) found an inverse relation between EF and adiposity, whereas Drummond et al (13) (7-d food diary) and Yannakoulia et al (14) (3-d food diary) found no such relation. However, Longnecker et al (36) found that the day-to-day variation in a person's EF is larger than between-subject variation, which suggests that data from multiple days of a food diary are needed to measure a person's EF with precision. It has also been suggested that the use of a 7-d food diary provides a more accurate measurement of EI and is more representative of usual intake than is the use of food-frequency questionnaires or dietary recall (37–40). Considering the fact that the reliability of food estimates increases along with the increase in the number of days of survey recorded, we decided to assess dietary intake by using a 7-d food diary.

The method of assessment of body fatness can have an effect on the relation between EF and body composition. Most studies of EF used BMI or included a measure of body composition using skinfold-thickness measurements taken with calipers to assess body fatness. Yannakoulia et al (14), in the only study to have used dual-energy X-ray absorptiometry for the measurement of body composition, did not find any relation between EF and adiposity. It is important to note that, in the present study, the BMI range was 19–29, whereas, in the study of Yannakoulia et al (14), it was 19–39. The difference in the BMI range may have had an effect on the results. Given that controversy persists regarding the effect of EF on body composition in persons of various adiposities, future studies should pay particular interest to this aspect.

Eating frequency and energy intake

The positive correlation found in the present study between EF and EI suggests that women did not compensate for more frequent eating episodes by reducing the quantity of kilocalories consumed per eating occasion. These results are consistent with other recent studies (13, 14). Poor EI compensation is generally associated with obesity (41, 42), but, in the present study, it was related to leanness. Women who ate more frequently were leaner than others, even if the former group tended to eat more. This finding emphasizes the need to measure energy output when the relation between EF and body composition is investigated. Indeed, physical activity is an important factor in the prevention of weight gain and the promotion of weight-loss maintenance (43, 44). Even though higher PAEE in women may promote a higher EF and EI to meet the increased energy requirements, increased physical activity may be sufficient to prevent weight gain.

Eating frequency, physical activity energy expenditure, and peak oxygen consumption

In the present study, EF was positively correlated with PAEE and $\dot{V}O_{2peak}$. These correlations could explain why women with higher EF also tended to have lower adiposity, despite a higher EI, as was previously proposed (13, 14). Indeed, a physically active lifestyle could compensate for the positive association between EF and EI with respect to body composition. Only 2 studies have included a measure of PAEE in women (13, 14). When physical activity was assessed, it was mostly done with the use of a self-reported questionnaire or physical activity diary, which can increase the rate of overreporting of physical activity (45). In the present study, the use of more objective measures (ie, accelerometer and $\dot{V}O_{2peak}$) to assess PAEE and physical fitness may have contributed to the presence of a relation between EF and PAEE. Physical fitness has not been assessed in previous studies of EF and body composition, and this aspect is a novel contribution to the field.

Eating frequency and body composition after control for physical activity energy expenditure and peak oxygen consumption

To investigate the effect of PAEE and $\dot{V}O_{2peak}$ on the relation between EF and body composition, we performed partial correlations. The results showed that, after correction for PAEE and $\dot{V}O_{2peak}$, the associations between adiposity and EF were no longer significant, which suggests that the relation between EF and body composition may be an artifact of higher PAEE and greater physical fitness. Therefore, a higher EF resulting from higher physical activity and greater physical fitness could very well be a marker of a physically active lifestyle, at least in leaner persons.

Conclusion

Results from the present study suggest that the negative relation between EF and body composition, despite higher EI, may in fact be explained by greater physical fitness and PAEE in premenopausal women. Although more studies are needed to confirm this finding, it can be concluded that a higher eating frequency in the absence of physical activity may not lead to enhanced adiposity control. Future research on this relation should include subjects with a wide range of adiposity, and there is also a need for longitudinal data documenting the relation between eating occasions and adiposity.

The authors' responsibilities were as follows—IS, DP, RR-L, and ED: the conception of the study; KD and M-JC: data collection; ED and KD: analysis and interpretation of the data; KD: wrote the manuscript; and all authors: critical revision of the manuscript. None of the authors had a personal or financial conflict of interest.

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APPENDIX A

Eating frequency (EF) and energy content and macronutrient composition of the meals, snacks, and drinks[1]

	Meals	Snacks	Drinks
EF (intake occasions/d)	2.8 ± 0.2	1.8 ± 0.9	1.0 ± 0.8
Energy intake (kcal/d)	1639.8 ± 355.1	371.5 ± 248.6	80.5 ± 80.9
Protein (g)	70.8 ± 14.5	8.7 ± 7.2	1.4 ± 1.7
Protein (% of energy)	17.3 ± 3.6	8.6 ± 2.6	8.9 ± 9.1
Carbohydrate (g)	197.0 ± 49.0	55.8 ± 38.0	13.0 ± 17.4
Carbohydrate (% of energy)	47.1 ± 6.1	59.1 ± 12.9	62.9 ± 27.1
Fat (g)	60.4 ± 17.7	13.2 ± 9.7	1.1 ± 1.9
Fat (% of energy)	32.4 ± 5.5	30.1 ± 11.7	10.6 ± 12.7
Alcohol (g)	7.5 ± 7.9	1.0 ± 2.3	2.2 ± 3.6
Alcohol (% of energy)	3.0 ± 3.1	1.5 ± 3.2	17.6 ± 27.6

[1] All values are mean ± SD. $n = 69$.

CHAPITRE 5

EFFETS DE LA TRANSITION MÉNOPAUSIQUE SUR LA DÉPENSE ÉNERGÉTIQUE : UNE ÉTUDE MONET.

Karine Duval, Denis Prud'homme, Rémi Rabasa-Lhoret, Irene Strychar, Martin Brochu, Jean-Marc Lavoie, Éric Doucet

L'article composant ce chapitre est intitulé :

«Effects of the Menopausal Transition on Energy Expenditure. A MONET group Study.»

(*European Journal of Clinical Nutrition 2013; 67: 407-411*)

Contribution des auteurs :

Denis Prud'homme, Rémi Rabasa-Lhoret, Irene Strychar, Martin Brochu, Jean-Marc Lavoie et Éric Doucet ont participé à l'élaboration de ce projet de recherche (MONET). Karine Duval a participé à la collecte des données et en a effectué l'analyse et l'interprétation. Elle a également réalisé la rédaction du manuscrit. Tous les auteurs ont participé à la révision du manuscrit.

RÉSUMÉ

Objectif : L'objectif de cette étude était de mesurer l'impact de la transition ménopausique sur les déterminants associés à la dépense énergétique.

Méthodes : Cent deux femmes préménopausées (âge : 49,9 ± 1,9 ans; IMC : 23,3 ± 2,2 kg/m²) ont été suivies pendant 5 ans. La composition corporelle (DXA), la dépense énergétique associée à l'activité physique (accéléromètre), la dépense énergétique de repos et l'effet thermique des aliments (calorimétrie indirecte) ont été mesurés à chaque année.

Résultats : Une diminution significative de la dépense énergétique totale a été observée dans le temps chez les femmes post-ménopausées ($P < 0,05$), ce qui est principalement attribuable à une diminution de la dépense énergétique associée à l'activité physique ($P < 0,05$). Bien que la dépense énergétique de repos moyenne soit restée stable dans le temps chez les femmes post-ménopausées, une augmentation significative, au cours de la période de 5 ans, a été notée chez les femmes qui étaient en transition ménopausique à l'année 5 ($P < 0,05$). Enfin, il a été observé que le temps consacré à pratiquer de l'activité physique d'intensité modérée a diminué et le temps consacré à pratiquer des activités sédentaires a augmenté au cours de la transition ménopausique ($P < 0,05$).

Conclusion : Ces résultats suggèrent que la transition ménopausique est accompagnée d'une diminution de la dépense énergétique, principalement caractérisée par une diminution de la pratique d'activité physique, et de l'adoption d'un mode de vie plus sédentaire.

European Journal of Clinical Nutrition (2013) 67, 407–411

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ORIGINAL ARTICLE

Effects of the menopausal transition on energy expenditure: a MONET Group Study

K Duval[1], D Prud'homme[2], R Rabasa-Lhoret[3,4,5], I Strychar[5,6], M Brochu[7,8], J-M Lavoie[9] and É Doucet[2]

OBJECTIVES: Factors that influence weight gain during the menopausal transition are not fully understood. The purpose of this study was to investigate changes in energy expenditure (EE) across the menopausal transition.

METHODS: In all, 102 premenopausal women (age: 49.9 ± 1.9 years; body mass index: 23.3 ± 2.2 kg/m^2) were followed for 5 years. Body composition (dual-energy X-ray absorptiometry), physical activity EE (accelerometer), resting EE and thermic effect of food (indirect calorimetry) were measured annually.

RESULTS: Total EE decreased significantly over time in postmenopausal women ($P < 0.05$), which was mostly due to a decrease in physical activity EE ($P < 0.05$). Although average resting EE remained stable over time in postmenopausal women, a significant increase, over the 5-year period, was noted in women who were in the menopausal transition by year 5 ($P < 0.05$). Finally, the time spent in moderate physical activity decreased and the time spent in sedentary physical activity increased during the menopausal transition ($P < 0.05$).

CONCLUSION: These results suggest that menopausal transition is accompanied with a decline in EE mainly characterized by a decrease in physical activity EE and a shift to a more sedentary lifestyle.

European Journal of Clinical Nutrition (2013) **67,** 407–411; doi:10.1038/ejcn.2013.33; published online 20 February 2013

Keywords: energy balance; energy expenditure; menopausal transition; body composition

INTRODUCTION

The menopausal transition is associated with a risk to increase body weight and adiposity.[1] Weight gain observed in middle-aged women at this time seems to be more closely associated with chronological aging rather than menopause *per se*.[2–5] On the other hand, changes in body composition and in fat distribution are influenced by the hormonal changes occurring at menopause, as well as by chronological aging.[6–7] Although hormonal changes associated with menopause and chronological aging may have a role in the changes of body weight and composition in women, identifying modifiable factors that can prevent or attenuate these changes is of great relevance.[8]

Few studies have investigated factors associated with energy balance during the menopausal transition. Although resting energy expenditure (REE) decreases with age,[9] the loss of ovarian function and the loss in muscle mass observed in postmenopausal women may also explain decline.[10] A 4-year study showed a significant decrease in REE over time in middle-aged women.[11] However, this decrease was 1.5 times greater in women who became postmenopausal when compared with those who remained premenopausal. Estrogens also appear to have an impact in the regulation of physical activity in both rodents and humans.[12–13] Lovejoy *et al.*[11] showed a significant decrease in leisure-time physical activity during the menopausal transition. Spontaneous physical activity, measured in a whole-room calorimeter, was also decreased by 30–40% in both post- and premenopausal women, suggesting an age-related decline rather than a specific effect of menopause.[11,14] Thus, changes in EE could have an important role in weight gain during the menopausal transition. However, at present, little is known about the relationship between EE and menopause.

To our knowledge, there have been only four longitudinal studies related to changes in EE during the menopausal transition.[2,5,11,15] However, most of them have only measured the physical activity component of EE with self-reported questionnaire.[2,5,15] One study used direct measures of body composition and EE (whole-room calorimeter and accelerometer).[11] The accelerometers were worn for only four consecutive days and 24-h EE was obtained in a small subset of women. The thermic effect of food (TEF) and the time spent in physical activity of different intensities have never been investigated during the menopausal transition.

This study was performed to determine changes in energy expenditure in women going through the menopausal transition. We hypothesized that women who will have become postmenopausal at the end of the study will show greater decrease in EE (REE and physical activity EE (PAEE)).

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Received 9 July 2012; revised 19 December 2012; accepted 21 December 2012; published online 20 February 2013

METHODS

Participants

Participants were recruited using community advertising and referrals from the Ob/Gyn clinics. Premenopausal women were included if they met the following criteria: (1) premenopausal status (two menstruations in the last 3 months, no increase in cycle irregularity in the 12 months before testing and a plasma follicular-stimulating hormone level <30 IU/L as a mean of verification), (2) aged between 47 and 55 years, (3) non-smoker, (4) body mass index (BMI) between 20 and 29 kg/m^2, and (5) reported weight stability (±2 kg) for 6 months or more before enrollment in the study. Exclusion criteria were (1) pregnancy or having plans to become pregnant, (2) medical problems that could have interfered with outcome variables, including cardiovascular and/or metabolic diseases, (3) taking oral contraceptives or hormone therapy, (4) high risk for hysterectomy, and (5) history of drug and/or alcohol abuse. As described by Abdulnour *et al.*,[7] of the 314 calls received, 102 women were found eligible. Among them, 11 dropped out of the study for personal reasons. Consequently, a total of 91 Caucasian women completed the 5-year longitudinal study. Further details of the MONET (Montreal-Ottawa New Emerging Team) menopausal transition study design and recruitment are provided elsewhere.[7]

As not all women had completed measurements for all of the EE variables every year, the number of participants varies across analyses for each EE variables (*n* range from 39 to 58). This study received approval from the University of Ottawa and the Montfort Hospital ethics committees, and written consent was obtained from each participant.

Design

The 5-year menopausal transition study was observational, with all outcomes measured at baseline and annually for 5 years. As long as women were premenopausal, they were always tested on days 1–8 of the follicular phase of the menstrual cycle, that is, when estrogens and progesterones are at their lowest concentrations.

Menopausal status

Menopausal status was determined yearly by self-reported questionnaire about menstrual bleeding and its regularity. Follicle-stimulating hormone was measured yearly during the early follicular phase and was used as a mean of verification of the menopausal status. Women were classified as *premenopausal*, if they reported no changes in menstrual cycle frequency; *menopausal transition*, if they reported irregular cycles characterized by variable cycle length >7 days different from normal and/or ⩾2 skipped cycles and an interval of ⩾60 days of amenorrhea; and finally women were classified as *postmenopausal* based on their final menstrual period (FMP) and confirmed by 12 months of amenorrhea and follicle-stimulating hormone >30 IU/L.[16]

Anthropometric measurements

Body weight and height were measured with a BWB-800AS digital scale and a Tanita HR-100 height rod (Tanita Corporation of America Inc., Arlington Heights, IL, USA), respectively, while participants were wearing a hospital gown and no shoes. Body composition was measured by using dual-energy X-ray absorptiometry (GE-LUNAR Prodigy module; GE Medical Systems, Madison, WI, USA). Coefficient of variation and correlation for percentage of body fat (%BF) measured in 12 healthy subjects tested in our laboratory were 1.8% and $r = 0.99$, respectively.

Resting energy expenditure and Thermic effect of food

REE and TEF were measured by indirect calorimetry (Deltatrac II metabolic cart; SensorMedics, Yorba Linda, CA, USA). REE was measured for 30 min after a 12-h overnight fast. Subjects had to rest quietly in the supine position for 20 min before the measurement. The first and last 5 min were excluded and only those obtained during 6–25 min were used in the calculation. The participant then consumed a standardized breakfast consisting of two slices of whole wheat bread (80 g), peanut butter (20 g), raspberry jam (20 g), cheddar cheese 27% milk fat (20 g) and orange juice (250 ml). The total energy content was 575 kcal (2400 kJ), and its food quotient was 0.89 (57% carbohydrates, 13% protein, 30% lipids). Subjects ate everything within 10 min. For postprandial EE, 15-min sampling periods were performed every 30 min for 3 h during the postprandial period.[17] A mean value (in kcal/min) for each of the six postprandial EE measurements was calculated. The TEF was obtained by subtracting REE from postprandial EE for each of the mean values obtained for the six sampling periods. Total TEF was calculated by multiplying the mean value of each of the six sampling periods by 30 min. These six values were then added together to obtain TEF for the 180-min period. TEF expressed in percentage was also calculated as the increase in EE (over baseline REE), expressed as a percentage of the energy content of the test meal. EE was calculated according to the Weir equation.[18] Coefficient of variation and correlation for the determination of REE with the Deltatrac II metabolic cart in our laboratory were 2.3% and $r = 0.98$, respectively, as determined in 12 healthy subjects.

Physical activity energy expenditure

Multidirectional accelerometry units were used (Actical; Mini Mitter Co., Inc., Bend, OR, USA). The Actical has been validated to measure physical activity in adults[19] and has shown better instrument reliability than other accelerometer models.[20] It was used to estimate daily EE from physical activities and time spent at sedentary and moderate physical activity intensity. Participants were asked to wear the accelerometer upon waking up and took it off just before going to bed for 7 consecutive days. Such a duration was reported to result in 90% reliability for the measurement of PAEE in both male and female subjects.[21] The accelerometer was worn over the right hip as it best predicts EE ($r = 0.92–0.97$).[22]

Total energy expenditure

Total EE (TEE) was calculated by using the following formula:

$$TEE = (PAEE + REE) \times 1.11 \quad (1)$$

where the factor 1.11 corresponds at the TEF, and was fixed at 10% of TEE.

Statistical analysis

SPSS was used for all analyses (version 17.0; SPSS Inc., Chicago, IL, USA). Two-way repeated-measures analyses of variance (ANOVA), controlled for fat mass (FM) and fat-free mass (FFM) at year 5, were used to determine main effects of time and menopausal status on EE variables. *Post hoc* tests were performed with Tukey–Kramer and adjustment was used for multiple comparisons. These analyses thus included data collected annually for 5 years. Only cases with complete data at all measurement points were retained. Paired comparison tests were performed to determine differences between year 0 and years before and after menopause onset. In these analyses, year 0 is considered the year within FMP (menopause onset). Data before and after menopause onset were expressed as the percent of the values at year 0, which was fixed at 100%. Data are presented as means ± s.d. All effects were considered significant at $P < 0.05$.

RESULTS

Characteristics of the participants

Baseline characteristics of participants are presented in Table 1. At the onset of the study, women were all premenopausal. By the end of year 5, 4% ($n = 4$) were still premenopausal, 29% ($n = 26$) were in the menopausal transition and 67% ($n = 61$) had become postmenopausal. As reported previously, Abdulnour *et al.*[7] reported significant increases for FM, %BF, trunk FM and visceral fat during the menopausal transition. No significant changes were observed for body weight and FFM after the 5-year follow-up.

Menopausal status and energy expenditure changes over time

Women were divided *post hoc* based on their menopausal status at year 5: (1) women who remained premenopausal ($n = 4$) and those classified in the menopausal transition at year 5 ($n = 26$); (2) women classified as postmenopausal for <12 months (*Post*⩽*12 months*, $n = 22$); and (3) women who classified as postmenopausal for more than 12 months (*Post*>*12 months*, $n = 39$). Considering the small number of women who remained premenopausal, they were combined with women who were classified to be in the menopausal transition. No significant differences were found throughout the study for body weight and body composition (*Menopausal Transition*, $n = 30$) (data not shown). Postmenopausal status at year 5 in the *Post*⩽*12 months* group was confirmed *a posteriori*. Women in this group were contacted after the completion of the 5-year data collection to confirm their menopausal status.

Baseline EE variables were not significantly different between *Menopausal transition, Post ⩽ 12 months* and *Post > 12 months* groups (data not shown). Although Table 2 presents EE data for only years 1 and 5, analyses were performed using data from years 1 through 5. Significant main effects of time were observed for TEF, showing an overall increase for TEF during the 5-year follow-up for all groups (Table 2). Significant *menopausal status × time* interaction was observed for REE, revealing a significant increase in the Menopausal transition group only. Significant *menopausal status × time* interaction were also observed for PAEE and TEE, revealing a significant decrease in the *Post > 12 months* group only. Because the accelerometry data can be influenced by whether time spent awake changed over time, we did two-way repeated-measures ANOVA to determine main effect of time and menopausal status on time spent awake. No significant main effect of time and *menopausal status × time* interaction were observed for this variable (data not shown). There was no main effect of menopausal status on any of the EE variables (Table 2).

Regression analyses were performed to investigate relations between changes in EE and those in body weight and composition. The only significant regression was observed between FFM and PAEE for the *Post > 12 months* group ($r^2 = 0.16$, $P < 0.05$).

Table 1. Characteristics of the whole sample of subjects at baseline

Variable	n	*Value*
Age (years)	102	49.9 ± 1.9 (47–55)
Body weight (kg)	102	61.1 ± 6.7 (46.8–79.7)
Waist circumference (cm)	102	78.0 ± 6.6 (62.2–93.7)
BMI (kg/m^2)	102	23.3 ± 2.2 (19.3–28.8)
% Body fat	102	31.3 ± 6.5 (18.2–42.4)
Fat mass (kg)	102	19.2 ± 5.3 (9.6–31.6)
Fat-free mass (kg)	102	41.3 ± 4.5 (27.6–52.9)
REE (kcal per day)	95	1224.1 ± 109.5 (946.0–1460.0)
TEF (kcal/180 min)	93	33.1 ± 8.5 (14.2–66.1)
TEF (%)	93	17.8 ± 3.8 (9.0–30.8)
PAEE (kcal per day)	86	802.4 ± 258.0 (326.3–1904.7)
Time sedentary (min per week)	86	6366.4 ± 746.7 (4601.0–8189.0)
Time moderate (min per week)	86	1598.8 ± 479.4 (628.0–2801.0)
TEE (kcal per day)	85	2249.3 ± 344.5 (1640.4–3662.0)

Abbreviations: BMI, body mass index; METs, metabolic equivalents; PAEE, physical activity energy expenditure; REE, resting energy expenditure; TEE, total energy expenditure; TEF, thermic effect of food; time moderate, time spent in moderate physical activity (3–6 METs); time sedentary, time spent in sedentary physical activity (1–1.5 METs). Values are mean ± s.d. (all such values).

Effect of the menopausal transition on energy expenditure changes

To further analyze the effect of menopausal transition on EE variables, paired comparison tests were performed to investigate the differences between years relative to FMP in women who became postmenopausal by the end of the study. These data are expressed as the percent of the values at year 0, which was fixed at 100%, and are shown in Table 3. Year 0 was the year within the FMP (or menopause onset), year 1 was considered as 1 year after FMP and year − 1 was considered as 1 year before FMP, and so on. There were no significant differences in PAEE and TEE in relation to menopause onset. REE was significantly higher at year + 2, whereas TEF was significantly higher at year + 1 relative to menopause onset. Moreover, TEF was significantly lower in the years preceding onset of menopause (− 4 and − 3), and %TEF was significantly lower at year − 4. Furthermore, time spent in sedentary physical activity tended to increase across the menopausal transition years and was significantly higher at year − 1. This variable continued to increase in the postmenopausal years (year + 1 and + 2) and was significantly higher at year + 1. Regarding the time spent in moderate physical activity, it was higher at year − 3 and decreased until the onset of menopause (year 0).

DISCUSSION

The present study provides longitudinal data on changes in EE that occur in women during the menopausal transition. We found that TEE was decreased in postmenopausal women, which was mostly explained by a decrease in PAEE. We also observed that the time spent in moderate physical activity was decreased and the time spent in sedentary physical activity was increased during the menopausal transition. Contrary to what was expected,

Table 2. Energy expenditure variables in response to time and menopausal status at year 5 (only values at baseline and year 5 are presented)

	Menopausal transition		*Post ⩽ 12 months*		*Post > 12 months*		*Repeated-measures ANOVA P-value*		
	Baseline	*Year 5*	*Baseline*	*Year 5*	*Baseline*	*Year 5*	*Time*	*Meno*	*Meno × time*
n	19	19	14	14	25	25			
REE (kcal per day)	1249.8 ± 115.7	1320.8 ± 145.1[a]	1222.6 ± 108.1	1213.4 ± 122.5	1213.6 ± 107.7	1232.6 ± 104.8	NS	NS	< 0.05
n	19	19	13	13	24	24			
TEF (kcal/180 min)	31.6 ± 6.8	36.2 ± 9.8[a]	33.2 ± 6.3	39.2 ± 7.1[a]	33.2 ± 7.0	33.6 ± 9.2[a]	< 0.01	NS	NS
TEF (%)	16.8 ± 2.8	18.0 ± 4.4[a]	17.8 ± 3.0	20.5 ± 3.8[a]	18.0 ± 3.5	17.8 ± 4.6[a]	< 0.05	NS	NS
n	12	12	11	11	18	18			
PAEE (kcal per day)	764.5 ± 276.8	890.1 ± 252.1	837.5 ± 259.5	887.7 ± 201.0	940.1 ± 340.7	751.4 ± 314.1[a]	NS	NS	< 0.05
Time sedentary (min per week)	6376.5 ± 877.8	6219.0 ± 837.7	6103.5 ± 817.1	6271.4 ± 469.8	6244.6 ± 731.0	6875.0 ± 1010.1	NS	NS	NS
Time moderate (min per week)	1506.8 ± 534.7	1683.5 ± 438.9	1788.1 ± 632.4	1687.9 ± 322.6	1749.8 ± 450.1	1495.3 ± 614.0	NS	NS	NS
n	10	10	11	11	18	18			
TEE (kcal per day)	2239.8 ± 381.6	2446.9 ± 312.9	2295.0 ± 355.4	2332.2 ± 275.0	2412.2 ± 429.0	2209.9 ± 419.9[a]	NS	NS	< 0.01

Abbreviations: Meno, menopausal status; METs, metabolic equivalents; NS, not significant; PAEE, physical activity energy expenditure; Post ⩽ 12 months, postmenopausal status ⩽ 12 months; Post > 12 months, postmenopausal status > 12 months; REE, resting energy expenditure; TEF, thermic effect of food; time moderate, time spent in moderate physical activity (3–6 METs); time sedentary, time spent in sedentary physical activity (1–1.5 METs); TEE, total energy expenditure. Analyses were controlled for fat mass and fat-free mass at year 5. Values are mean ± s.d. [a]Significant difference over time within menopausal status ($P < 0.05$ by *post hoc* Tukey's test).

Table 3. Changes in energy expenditure before and since menopause onset (year 0)

	Years before and since menopause onset						
	− 4	*− 3*	*− 2*	*− 1*	*0*	*1*	*2*
n	18	32	48	42	49	28	14
REE (kcal per day)	99.2 ± 6.6	99.3 ± 7.1	100.4 ± 9.8	101.1 ± 8.2	100%	103.0 ± 8.4	107.2 ± 9.6[a]
n	17	29	44	40	46	27	13
TEF (kcal per 180 min)	86.2 ± 19.8[a]	90.1 ± 23.6[a]	107.3 ± 51.1	96.5 ± 27.4	100%	111.2 ± 24.2[a]	107.7 ± 24.6
TEF (%)	89.2 ± 17.7[a]	93.0 ± 22.7	106.9 ± 44.4	97.3 ± 25.8	100%	107.1 ± 23.7	101.4 ± 23.2
n	16	30	41	36	46	21	12
PAEE (kcal per day)	98.6 ± 29.1	108.2 ± 26.8	104.8 ± 34.5	95.0 ± 29.5	100%	89.5 ± 28.2	96.3 ± 35.8
Time sedentary (min per week)	96.4 ± 10.3	96.9 ± 9.8	100.4 ± 13.2	104.4 ± 13.2[a]	100%	107.7 ± 12.4[a]	106.6 ± 13.5
Time moderate (min per week)	110.6 ± 33.1	112.6 ± 26.9[a]	108.7 ± 36.2	94.7 ± 25.2	100%	90.2 ± 36.6	94.6 ± 26.7
n	16	28	40	36	45	20	12
TEE (kcal per day)	97.9 ± 10.0	100.9 ± 12.5	99.8 ± 13.2	97.6 ± 11.8	100%	95.7 ± 11.0	101.6 ± 12.3

Abbreviations: METs, metabolic equivalents; PAEE, physical energy expenditure; REE, resting energy expenditure; TEE, total energy expenditure; TEF, thermic effect of food; time moderate, time spent in moderate physical activity (3–6 METs); time sedentary, time spent in sedentary physical activity (1–1.5 METs); Values are mean ± s.d. for each year expressed as the percent of the values at year 0 (menopausal onset), which was standardized to 100%. [a]Significantly different compared with year 0 ($P < 0.05$).

REE remained stable in postmenopausal women and a significant increase was noted in women who were in the menopausal transition by year 5.

There are several possible explanations for the decrease of EE during the menopausal transition. First, TEE tends to decrease in advancing age resulting mainly from changes in REE and PAEE.[10,23,24] Second, postmenopausal women no longer experience the luteal phase of the menstrual cycle, which is associated with a rise in EE.[10] Third, the loss of FFM in postmenopausal women, which was reported previously,[25,26] appears to be related with lower REE.[10] Finally, estrogens appear to play a role in the regulation of PAEE in both rodents and humans.[12,13] Indeed, estrogen deficiency can lead to weight gain in animals by decreasing spontaneous physical activity.[13] One study conducted by Lovejoy *et al.*[11] reported similar results to ours in 129 premenopausal women. In that study, the women (age: 47.2 ± 0.2 years; BMI: 27.1 ± 0.6 kg/m^2; %BF: 40.9 ± 0.9) were followed for 4 years and those who became postmenopausal by the end of the study showed a significant decrease in EE (sleeping EE, PAEE, spontaneous physical activity). In contrast to Lovejoy's study, we did not observe a decline in REE. In a cross-sectional study of 65 pre- and postmenopausal women, Van Pelt *et al.*[27] reported that the age-related decline in REE in sedentary women was not observed in women who exercise regularly. In this study, women had a relatively high level of fitness (33.8 ml O_2 per kg per min) and a high physical activity level (1.7). In the Lovejoy *et al.* study,[11] the mean physical activity level was 1.3,[28] which is associated with a sedentary lifestyle.[29] This difference in the level of physical activity can explain, in part, why we did not observe a decline in REE during the menopausal transition. Another explanation for this result is that no significant changes in FFM were noted, which appears to be related with changes REE.[10]

Similar to Lovejoy *et al.*,[11] we observed a reduction in TEE of approximately 200 kcal per day in postmenopausal women, which could be enough to cause significant weight gain over time. However, although we observed a decrease in EE in postmenopausal women, the mean body weight changed minimally over time.[7] This could be explained by a concomitant reduction in energy intake, which could offset the effects of a decrease in EE on energy balance.[30]

The major findings of this study are related to changes in PAEE and in time spent in physical activities at different intensities. The decrease in PAEE observed in postmenopausal women is consistent with the findings of other studies.[5,8,11,15,31] In addition to the changes in PAEE, we also observed changes in time spent in sedentary and moderate physical activity. These results extend the findings from previous studies demonstrating that, during the menopausal transition, women tend to shift to a more sedentary lifestyle. Associations between physical activity and weight gain during the menopausal transition have been observed in other studies.[2,5,15,31] In the Healthy Women Study, a prospective study of middle-aged women, Owens *et al.*[31] reported that women who had higher levels of physical activity at baseline had less weight gain over time. Moreover, women who increased their physical activity during the 3-year follow-up had the smallest increases in weight. In the SWAN study, Sternfeld *et al.*[5] also found that physical activity was inversely associated with changes in body weight. Findings from several cross-sectional and longitudinal studies have suggested that regular physical activity may help to attenuate or prevent the tendency for weight gain and adverse changes in body composition that can occur during the menopausal transition.[32–34] Indeed, it seems that regular physical activity, particularly at moderate to high intensity, could help to minimize changes in body weight and composition during the menopausal transition.[5,8,15,35] The most consistent behavioral factor contributing to weight gain during the menopausal transition seems to be a decrease in PAEE.

This study presents some limitations. First, the small sample size and the healthy homogenous population (healthy women with a BMI < 30 kg/m^2) limits the generalizability of our results. However, it is important to mention that 45% of the women aged between 40 and 59 years in the Canadian population present a BMI between 20 and 29 kg/m^2. Second, women were tested yearly, and thus measurements were not taken exactly 12 months prior, during and 12 months after their final menstrual period. Third, although 67% of the women became postmenopausal by year 5, the relatively short duration of the follow-up, particularly during the postmenopausal period (2 years only), represents another limitation. Finally, we combined women who remained premenopausal ($n = 4$) to those who were in the menopausal transition, resulting in the absence of a premenopausal control group. Nonetheless, the prospective design in a very well-characterized cohort of women allows for consideration of within-woman change and is more informative than cross-sectional design. Gold standard measures (DXA) for body composition and objective measures of EE were used. Finally, even if our population consisted of non-obese women, according to their BMI (WHO), 59% had a %BF > 30 and 32% had a %BF $\geqslant 35\%$, which are considered as overweight and obese, respectively, based on norms from the American College of Sports Medicine.[36]

CONCLUSION

In summary, this study suggests that menopausal transition is accompanied with a decline in EE mainly characterized by a decrease in PAEE and a shift to a more sedentary lifestyle. These results suggest that the participation in regular physical activity may represent a relevant strategy to attenuate the decline in EE as women approach and transition into menopause.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

We thank the participants for their devoted participation and the staff of Behavioral and Metabolic Research Unit (BMRU) for their contribution to this study. We especially want to thank Ann Beninato for her significant role in the collection of the data and overall study coordination. This study was supported by CIHR (Canadian Institute for Health Research) Grants: 63279 MONET study (Montreal-Ottawa New Emerging Team). K Duval is a recipient of the FRSQ (Fonds de la recherche en Santé du Québec) Doctoral support program. R Rabasa-Lhoret is a recipient of the FRSQ clinical researcher scholarship and holds the J-A DeSève chair.

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CHAPITRE 6

EFFETS DE LA TRANSITION MÉNOPAUSIQUE SUR L'APPORT ALIMENTAIRE ET L'APPÉTIT : UNE ÉTUDE MONET.

Karine Duval, Denis Prud'homme, Rémi Rabasa-Lhoret, Irene Strychar, Martin Brochu, Jean-Marc Lavoie, Éric Doucet

L'article composant ce chapitre est intitulé :

«Effects of the Menopausal Transition on Dietary Intake and Appetite. A MONET group Study.»

(En révision à la revue *European Journal of Clinical Nutrition*)

Contribution des auteurs :

Denis Prud'homme, Rémi Rabasa-Lhoret, Irene Strychar, Martin Brochu, Jean-Marc Lavoie et Éric Doucet ont participé à l'élaboration de ce projet de recherche (MONET). Karine Duval a participé à la collecte des données et en a effectué l'analyse et l'interprétation. Elle a également réalisé la rédaction du manuscrit. Tous les auteurs ont participé à la révision du manuscrit.

RÉSUMÉ

Objectif : L'objectif de cette étude était de mesurer l'impact de la transition ménopausique sur les déterminants associés à l'apport alimentaire et l'appétit.

Méthodes : Cent deux femmes préménopausées (âge : 49,9 ± 1,9 ans; IMC : 23,3 ± 2,2 kg/m²) ont été suivis pendant 5 ans. La composition corporelle (DXA), l'appétit (échelle visuelle analogue), la fréquence des repas, l'apport calorique et la composition en macronutriments (journal alimentaire de 7 jours et repas de type buffet) ont été mesurés à chaque année.

Résultats : Les analyses à mesures répétées ont révélé que l'apport calorique total et l'apport en glucides, mesurés à l'aide du journal alimentaire, ont diminué de façon significative dans le temps chez les femmes post-ménopausées à l'année 5 ($0,05 > P < 0,01$) comparativement aux femmes en transition ménopausique. Chez les femmes post-ménopausées à l'année 5, l'apport en lipides et en protéines a eu tendance à diminuer pendant la transition ménopausique ($P < 0,05$). Bien qu'une diminution de l'apport en lipides ait été observée pendant la transition ménopausique ($P < 0,05$), une augmentation significative de cette variable dans les années en post-ménopause a été notée ($P < 0,05$). Les apports spontanés en calories et en protéines ont également diminué au fil du temps et étaient plus élevés au cours des années précédant la ménopause ($P < 0,05$). Finalement, le désir de manger, la sensation de faim et la quantité de nourriture pouvant être ingérée ont augmenté pendant la transition ménopausique et sont restés à ce niveau plus élevé dans les années en post-ménopause ($0,05 > P < 0,001$).

Conclusion : Ces résultats suggèrent que la transition ménopausique est accompagnée d'une diminution de l'apport alimentaire et d'une augmentation de l'appétit.

Effects of the Menopausal Transition on Dietary Intake and Appetite. A MONET Group Study.

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ABSTRACT

Objective: The purpose of this study was to investigate changes in dietary intake and appetite across the menopausal transition. **Methods:** This was a 5-year observational, longitudinal study on the menopausal transition. The study included 102 premenopausal women at baseline (age: 49.9 ± 1.9 yrs; BMI: 23.3 ± 2.2 kg/m²). Body composition (DXA), appetite (visual analogue scale), eating frequency, energy intake (EI) and macronutrient composition (7-day food diary and buffet-type meal) were measured annually. **Results:** Repeated-measures analyses revealed that total EI and carbohydrate intake from food diary decreased significantly over time in women who became postmenopausal by year 5 ($P > 0.05$) compared to women in the menopausal transition. In women who became postmenopausal by year 5, fat and protein intakes decreased across the menopausal transition ($0.05 > P < 0.01$). Although a decrease in % fat intake was observed during the menopausal transition ($P < 0.05$), this variable was significantly increased in the postmenopausal years ($P < 0.05$). Spontaneous EI and protein intake also declined over time and were higher in the years preceding menopause onset ($P < 0.05$). Desire to eat, hunger and prospective food consumption increased during the menopausal transition and remained at this higher level in the postmenopausal years ($0.05 > P < 0.001$). **Conclusion:** These results suggest that menopausal transition is accompanied with a decrease in food intake and an increase in appetite.

Keywords: Energy balance, energy intake, eating frequency, appetite, menopausal transition, body composition

INTRODUCTION

The regulation of food intake and appetite in humans is under the influence of biological, psychological and social factors [1]. Although it has been observed that estrogen deficiency increases food intake and appetite in animals [2], there is little evidence to support this in postmenopausal women. Hormonal fluctuations during the menstrual cycle are known to affect energy intake (EI) [1, 3], but food intake during the menopausal transition has been much less studied. The few studies that have investigated this latter issue reported a slight decrease in the calories [4-5], protein and dietary fibers during the menopausal transition [4].

To our knowledge, three longitudinal studies investigated EI during the menopausal transition [4-6]. Two used food frequency questionnaire or 24-h recall to measure EI and did not present macronutrient composition [5-6]. One of these studies published used direct measures of body composition and measured EI with 4-day food record [4]. Interestingly, eating frequency (EF), appetite and objectively measured EI have never been investigated during the menopausal transition.

The objective of this study was to determine changes in dietary intake and appetite during the menopausal transition. We hypothesized that women who will have become postmenopausal at the end of the study will show greater increase in EI and appetite.

METHODS

Participants

Participants were recruited using community advertising and referrals from the Ob/Gyn clinics. Premenopausal women were included if they met the following criteria: (1) premenopausal status (two menstruations in the last 3 months, no increase in cycle irregularity in the 12 months before testing, and a plasma follicular-stimulating hormone level < 30 IU/L as a mean of verification), (2) aged between 47 and 55 years, (3) nonsmoker, (4) BMI between 20 and 29 kg/m², and (5) reported weight stability (± 2 kg) for 6 months or more before enrollment in the study. Exclusion criteria were (1) pregnancy or having plans to become pregnant, (2) medical problems that could have interfered with outcome variables including cardiovascular and/or metabolic diseases, (3) taking oral contraceptives or hormone therapy, (4) high risk for hysterectomy, and (5) history of drug and/or alcohol abuse. As described by Abdulnour *et al.* [7], of the 314 calls received, 102 women were found eligible. Among them, 11 dropped out of the study for personal reasons. Consequently, a total of 91 Caucasian women completed the 5-year longitudinal study. Further details of the MONET menopausal transition study design and recruitment are provided elsewhere [7].

Since not all women had completed measurements of all dietary intake and appetite variables for each of the 5 years of data collection, the number of participants varies across analyses for dietary intake and appetite variables (n range from 30 to 56). This study received approval from the University of Ottawa and the Montfort Hospital ethics committees, and written consent was obtained from each participant.

Design

This 5-year menopausal transition study was observational with all outcomes measured at baseline and every year during the course of this 5 year follow-up. As long as women were premenopausal, they were always tested on days 1–8 of the follicular phase of the menstrual cycle, *ie*, when estrogens and progesterone are at their lowest concentrations. Women were tested at the same time of day for all measurements every year. Participants were asked to refrain from any vigorous exercise for at least 24 h before the experimental sessions and were asked to abstain from consuming alcohol on the day prior to measurements.

Menopausal status

Menopausal status was determined yearly by self-reported questionnaire about menstrual bleeding and its regularity. Follicle-stimulating hormone (FSH) was measured yearly during the early follicular phase and was used as a mean of verification of the menopausal status. Women were classified as *premenopausal* if they reported no changes in menstrual cycle frequency; *menopausal transition* if they reported irregular cycles characterised by variable cycle length > 7 days different from normal and/or ≥ 2 skipped cycles and an interval of ≥ 60 days of amenorrhea; and finally women were classified as *postmenopausal* based on their final menstrual period (FMP) and confirmed by 12 months of amenorrhoea and FSH > 30 IU/L [8].

Body weight and composition

Body weight and height were measured with a BWB-800AS digital scale and a Tanita HR-100 height rod (Tanita Corporation of America, Inc, Arlington Heights, IL), respectively, while participants were wearing a hospital gown and no shoes. Body composition was measured by using dual-energy X-ray absorptiometry (DXA; GE-LUNAR Prodigy module; GE Medical Systems, Madison, WI.). Coefficient of variation and correlation for percentage of body fat (%BF) measured in 12 healthy subjects tested in our laboratory were 1.8% and $r = 0.99$, respectively.

Standardized breakfast and appetite ratings

A standardized breakfast was served after a 12h overnight fast [575 kcal (2400 kJ) and FQ = 0.89 (57% carbohydrates, 13% proteins, 30% lipids)]. Visual analogue scale measurements were taken before, immediately after and every 30 min for a period of 3h after the standardized breakfast [9]. The answer to the following questions were used to determine their 'desire to eat', 'hunger', 'fullness', and 'prospective food consumption (PFC)', respectively: 1) 'How strong is your desire to eat?' (very weak – very strong); 2) 'How hungry do you feel?' (not hungry at all – as hungry as I have ever felt); 3) 'How full do you feel?' (not full at all – very full); and 4) 'How much food do you think you could eat?' (nothing at all – a large amount). The measurements before breakfast were considered as the fasting measurement, and post-meal area under the curve (AUC) were calculated with the trapezoid method as previously described [10]. Appetite rating responses at 0, 30, 60, 90, 120, 150, and 180 min were considered in the calculation of the AUC.

Dietary Assessment

Food Diary

Energy and macronutrient intakes were assessed with a 7-day food diary. The time and place of eating of food were also recorded. Participants received oral and written instructions on recording their food intake. Recorded data were carefully verified upon return of the food diary to obtain forgotten data or correct misreported data. The diaries were analysed with Food Processor SQL program (version 10.8; ESHA Research, Salem, OR) using the 2007 Canadian Nutrient Data File.

Buffet-type meal

A buffet-type meal was offered at lunch time (3 hours after a standardized breakfast) and subjects were instructed to eat *ad libitum* [11-13]. All foods were weighed before and at the end of the buffet to the nearest gram. Energy, protein, lipid, carbohydrate and dietary fiber intakes were calculated with the Food Processor SQL program (version 10.8; ESHA Research, Salem, OR) using the 2007 Canadian Nutrient Data File.

Establishing the number of eating occasions

Data from the food diaries were also used to calculate the average number of eating occasions per day, *ie*, EF. Eating occasions were defined as any occasion when food was consumed [14]. The definition excluded drinks (alcoholic drinks, soft drinks, juices, water, or coffee and tea) that were consumed in the absence of food. If 2 eating occasions occurred in ≤ 15 min, both events were counted as a single eating occasion. When > 15 min separated 2 eating occasions, those occasions were considered distinct eating occasions. This method of calculating the number of eating occasions was described previously [14-17].

Assessment of underreporting

Previous research in dietary assessment has indicated persistent errors in self-reported EI [18-19]. The use of invalid dietary data can biased the understanding of the association between diet and health or body weight [20]. When body weight is stable, total energy expenditure (TEE) is equivalent to EI. Thus, the ratio of reported EI to TEE should be equal to 1. In this study, underreporting was assessed by direct comparison of recorded EI and measured energy expenditure (EE). The ratio between EI and TEE was determined for each subject. Total EE was calculated by using the following formula:

$$TEE = (PAEE + REE) \times 1.11 \qquad (1)$$

where the factor 1.11 corresponds at the thermic effect of food (TEF), and was fixed at 10% of TEE. Physical activity EE (PAEE) was assessed by using 7-day accelerometry (Actical; Mini Mitter Co, Inc, Bend, OR), and resting EE (REE) was measured by indirect calorimetry (Deltatrac II metabolic cart; SensorMedics Corporation, Yorba Linda, CA). Participants with a ratio of reported EI to EE < 0.74 were classified as underreporters and removed from statistical analysis for EI, macronutrient composition and EF measured by 7-day food diary [21-22].

Statistical analysis

SPSS was used for all analyses (version 17.0; SPSS Inc, Chicago, IL, USA). Two-way repeated-measures analyses of variance (ANOVA) were used to determine main effects of time and menopausal status on EI, macronutrient composition, EF and appetite variables. *Post hoc* test were done with Tukey-Kramer and adjustment was used for multiple comparisons. These analyses thus included data collected annually for 5 years. Only cases with complete data at all measurement points were retained. Paired comparison tests were performed to determine differences between year 0 and years before and after menopause onset. In these analyses, year 0 is considered the year within FMP (menopause onset). For dietary intake and AUC appetite variables, data before and after menopause onset were expressed as the percent of the values at year 0, which was fixed at 100%. Regarding fasting appetite variables, data before and after menopause onset were expressed as the change in mm of the values at year 0. Data are presented as means ± SD. All effects were considered significant at $P < 0.05$.

RESULTS

Characteristics of the participants

At baseline, women were all premenopausal (age: 49.9 ± 1.9 yrs; body weight: 61.6 ± 6.7 kg; BMI: 23.3 ± 2.2 kg/m²; %BF: 31.3 ± 6.5 %; FM; 19.2 ± 5.3 kg; FFM: 41.3 ± 4.5 kg). As reported previously [7], significant increases for fat mass (FM), %BF, trunk FM and visceral fat were noted while no significant changes were seen for body weight and fat-free mass (FFM) after the 5-year follow-up.

Low energy reporters

Low energy reporters were excluded from the analyses. Twenty-six subjects (30.1%) had ratios of EI/TEE below the cutoff of 0.74 and were identified as underreporters. Data from a total of 59 women were thus included in the final analyses for EI, macronutrient composition and EF measured by 7-day food diary.

Dietary intake and appetite changes over time

Women were divided *post hoc* based on their menopausal status at year 5: 1) women who remained premenopausal (n = 4) and those classified in the menopausal transition at year 5 (n = 26); 2) women classified as postmenopausal for less than 12 months (*Post ≤ 12 months*, n = 22); and 3) women who classified as postmenopausal for more than 12 months (*Post > 12 months*, n = 39). Considering the small number of women who remained premenopausal, they were combined with women who were classified to be in the menopausal transition. No significant differences were found throughout the study for body weight and body composition (*Menopausal Transition*, n = 30) (data not shown). Postmenopausal status at year 5 in the *Post ≤ 12 months* group was confirmed *a posteriori*. Women in this group were contacted after the completion of the 5-year data collection to confirm their menopausal status.

Baseline values for EI, macronutrient composition, EF and appetite were not significantly different between *menopausal transition*, *Post ≤ 12 months* and *Post > 12 months* groups (data not shown). Although **Table 1 and 2** present dietary intake and appetite data for only years 1 and 5, analyses were performed using data from years 1 through 5.

Energy intake, macronutrient composition and eating frequency

Significant main effects of time were observed for protein, fat and dietary fiber intakes (grams), showing an overall decrease in time for all groups (**Table 1**). A significant main effect of time was also observed for EF, showing an increase over time for all groups. Significant *menopausal status x time* interactions were observed for EI and carbohydrate intake (grams). The Tukey-Kramer *post hoc* test revealed a significant decrease for EI and carbohydrate intake (grams) in the *Post > 12 months* group only. There was no main effect of menopausal status on any of the EI, macronutrient composition and EF variables.

Regarding *ad libitum* EI and macronutrient composition measured with a buffet-type meal only a significant *menopausal status x time* interaction for % protein intake was observed, revealing a significant increase in the *Post > 12 months* group only (20.0 ± 5.6 (year 1) vs. 22.5 ± 6.0 (year 5), $P < 0.05$). Furthermore, there was a main effect of menopausal status on % protein intake, showing a difference between the *menopausal transition* and the *Post > 12 months* groups ($P < 0.05$, data not shown).

Appetite

Significant main effects of time were observed for fasting and AUC desire to eat and hunger, showing an overall increase in time for these variables for all groups (**Table 2**). A significant decrease of fasting fullness was also observed over the 5-year follow-up. A main effect of time almost reaches significance for fasting prospective food consumption (PFC) (P = 0.054). There was no main effect of menopausal status and *menopausal status x time* interaction on any of the appetite variables.

Effect of the menopausal transition on dietary intake and appetite changes

To further analyze the effect of menopausal transition on dietary intake and appetite, paired comparison tests were performed to investigate the differences between years relative to FMP in women who became postmenopausal by the end of the study. For dietary intake and AUC variables, the data are expressed as the percent of the values at year 0, which was fixed at 100. Regarding fasting appetite variables, the data are expressed as the change in mm of the values at year 0**.** Year 0 was the year within the FMP (or menopause onset), year 1 was considered as one year after FMP and year -1 was considered as one year before FMP, and so on. Total EI, and protein and fat intakes (grams) from 7-day food diary were significantly higher in year -2 and decreased until the onset of menopause (year 0) (**Table 3**). Although % fat intake obtained from 7-day food diary decreased across the menopausal transition years, this variable increased in the postmenopausal years and was significantly higher at year +1. Percent protein and carbohydrate intakes were significantly lower at year -4 and -3, respectively. Energy intake from buffet-type meal tended to decrease across the menopausal transition years and was significantly lower at year +1 compared with menopause onset **(Table 3)**. Relative spontaneous protein intake was significantly higher in the postmenopausal years. Fasting desire to eat, fasting hunger (**see Figure**

1 Panel A) and fasting PFC were significantly lower during the menopausal transition years and increased until the onset of menopause. These variables remained at this higher level in the postmenopausal years (year +1 and +2). No significant change was observed for fasting fullness during the menopausal transition. AUC desire to eat and hunger (**see Figure 1 Panel B**) tended to increase across the menopausal transition years and was significantly higher at year +2 compared with menopause onset.

DISCUSSION

We found that total EI and carbohydrate intake decreased significantly over time in women who became postmenopausal by year 5. Furthermore, fat and protein intakes also decreased across the menopausal transition. Although a decrease in % fat intake was observed during the menopausal transition, this variable was significantly increased in the years after menopause onset. Buffet EI and protein intake also declined over time and were higher in the years preceding menopause onset. Lastly, appetite increased during the menopausal transition and remained higher in the postmenopausal years.

In the present study, a decrease in EI in postmenopausal women was observed, which is the opposite of what has been reported in ovariectomized rats [1-3]. However, the present results on EI are consistent with results reported in other studies that showed a decrease in EI across the menopausal transition [4-5]. Although we showed a decrease in EI in postmenopausal women (approximately 254 kcal/day), the mean body weight changed minimally over time [7]. This could be likely explained by a reduction in EE (approximately 200 kcal/day), mainly characterized by a decrease in physical activity EE and a shift to a more sedentary lifestyle, that we have reported previously [23]. In the present study, we found that changes in EI were significantly correlated with changes in PAEE ($r=0.26$, $P<0.05$). Moreover, women who may be more concerned about their weight at the time of menopause, may voluntarily change dietary patterns to avoid weight gain [24]. Similar to results from Lovejoy et al. [4], we noted a reduction in protein intake over time during the menopausal transition, which could possibly impact satiety [25]. Previously published data suggest that estrogen deficiency in animals resulted in an increase in food intake with a macronutrient-specific increase in fat intake [26]. In the present study, although % fat intake decreased across the menopausal transition years, this variable increased during the postmenopausal years. A diet low in fat could be beneficial in women approaching menopause. Indeed, a randomized clinical trial conducted over a 5-y period aimed at preventing weight gain during menopause showed that a diet low in fat (25%) was associated with better weight maintenance during the menopausal transition [27]. Similar to results from the food diaries, a decrease in EI, protein and fat intakes were also noted during the *ad libitum* buffet.

To our knowledge, this is the first study of appetite-related variables during the menopausal transition. Our results show that desire to eat, hunger and PFC increased during the menopausal transition and remained higher in the postmenopausal years. Results remained significant after adjustments for changes in EI. These results may be partly explained by the observation that ghrelin level was shown to be higher during the menopausal transition compared to both pre- and postmenopausal women [28]. The observed changes in appetite in the present study could indicate a risk for positive energy balance and weight gain over time. However, we did not observe an increase in EI during the menopausal transition. Eating behaviors, such as dietary restraint, could explain the fact that we have observed a decrease in EI and an increase in appetite. Nevertheless, in the present study, no significant changes in dietary restraint [measured by the Three-Factor Eating Questionnaire [29]] were noted (data not shown).

This study presents some limitations. First, the small sample size and the healthy homogenous population (healthy women with a BMI less than 30 kg/m^2) limits the generalizability of our results. However, it is important to mention that 45% of the women aged between 40 to 59 years in the Canadian population present a BMI between 20 and 29 kg/m^2. Second, although our population was non-obese women based on BMI, 59% had a %BF >30% and 32% had a %BF ≥ 35%, which are considered as overweight and obese, respectively, based on the American

College of Sports Medicine [30]. Third, appetite can differ across the day. In our study, the measurement of appetite was done only in the morning over a 3-hour period up until lunch time. However, it was shown that appetite sensations measured in response to a standardized breakfast test meal, as we used in our study, represented markers of overall intake [31-32]. Fourth, although 67% of the women became postmenopausal by year 5, the relatively short duration of the follow-up, particularly during the postmenopausal period (2 years only), represents another limitation. Finally, women who remained premenopausal (n=4) were combined to those who were in the menopausal transition resulting in the absence of a premenopausal control group. Nonetheless, the prospective design in a very well-characterized cohort of women allows for consideration of within-subject change and is more informative than cross-sectional design. Moreover, the present study took measures to ensure that underreporting did not bias the results. We screened the individual food diary results for underreporting by using validates procedures [21-22] and we excluded all low energy reporters from the analyses. Finally, gold standard measure (DXA) for body composition and objective measures of EI and appetite were used.

CONCLUSION

In summary, this study suggests that menopausal transition is accompanied with a decrease in EI and an increase in appetite. Although middle-aged women tend to experience changes in body composition, these changes do not seem to be the result of an increase in EI.

Acknowledgements

The authors would like to thank the participants for their devoted participation and to the staff of Behavioural and Metabolic Research Unit (BMRU) for their contribution to this study. We especially want to thank Ann Beninato for her significant role in the collection of the data and overall study coordination. This study was supported by CIHR (Canadian Institute for Health Research) grants: 63279 MONET study (Montreal Ottawa New Emerging Team). K Duval is a recipient of the FRSQ (Fonds de la recherche en Santé du Québec) Doctoral support program. R Rabasa-Lhoret is a recipient of the FRSQ clinical researcher scholarship and holds the J-A DeSève chair.

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Table 1. Dietary intake variables in response to time and menopausal status (Only values at baseline and year 5 are presented)

	Menopausal Transition		Post ≤ 12 months		Post > 12 months		Repeated Measures ANOVA *P*-value		
	Baseline	Year 5	Baseline	Year 5	Baseline	Year 5	Time	Meno	Meno x Time
n	10	10	9	9	11	11			
7-day food diary									
EI (kcal/day)	2289.9 ± 447.4	2143.9 ± 308.9	2175.8 ± 381.5	2139.4 ± 440.1	2098.7 ± 255.7	1845.2 ± 319.1*	<0.05	NS	<0.05
Protein (%)	15.8 ± 2.7	16.0 ± 2.4	15.3 ± 3.4	16.5 ± 2.5	15.9 ± 2.5	17.7 ± 3.1	NS	NS	NS
Carbohydrate (%)	51.5 ± 4.8	49.9 ± 4.5	49.7 ± 3.9	52.9 ± 4.8	51.0 ± 5.2	49.6 ± 8.0	NS	NS	NS
Fat (%)	32.2 ± 3.9	33.6 ± 5.5	33.2 ± 5.6	30.0 ± 2.6	30.1 ± 10.5	32.7 ± 4.1	NS	NS	NS
Protein (g)	88.1 ± 21.7	86.1 ± 20.3*	82.5 ± 19.6	86.5 ± 15.5*	82.6 ± 9.8	81.2 ± 16.8*	<0.05	NS	NS
Carbohydrate (g)	287.2 ± 63.2	267.2 ± 45.1	269.5 ± 48.0	284.9 ± 70.6	268.6 ± 50.4	230.0 ± 60.5*	NS	NS	<0.05
Fat (g)	80.3 ± 21.8	79.8 ± 15.4*	81.5 ± 23.8	71.5 ± 16.3*	70.5 ± 26.0	66.6 ± 12.3*	<0.05	NS	NS
Dietary fiber (g)	24.4 ± 15.2	24.4 ± 7.0*	23.7 ± 7.6	27.5 ± 7.9*	27.7 ± 9.7	26.8 ± 7.9*	<0.05	NS	NS
EF (eating occasions/day)	4.4 ± 0.9	5.1 ± 1.0*	4.9 ± 1.0	5.5 ± 1.5*	4.6 ± 0.8	4.8 ± 1.0*	<0.01	NS	NS

Post ≤ 12 months: postmenopausal status ≤ 12 months; Post > 12 months: postmenopausal status > 12 months; Meno: menopausal status; EI: energy intake; EF: eating frequency. NS: not significant. Values are mean ± SD. *Significant difference over time within menopausal status ($P < 0.05$ by *post hoc* Tukey's test).

Table 2. Appetite variables in response to time and menopausal status (Only values at baseline and year 5 are presented)

	Menopausal Transition		Post ≤ 12 months		Post > 12 months		Repeated Measures ANOVA *P*-value		
	Baseline	Year 5	Baseline	Year 5	Baseline	Year 5	Time	Meno	Meno x Time
n	18	18	13	13	25	25			
Fasting desire to eat (mm)	71.7 ± 45.0	97.4 ± 44.9*	86.8 ± 32.4	102.7 ± 32.6*	79.9 ± 41.5	103.8 ± 38.7*	<0.001	NS	NS
n	17	17	10	10	24	24			
Fasting hunger (mm)	66.0 ± 38.1	93.2 ± 41.1*	70.5 ± 34.8	102.9 ± 28.3*	77.7 ± 34.6	101.2 ± 35.6*	<0.001	NS	NS
Fasting fullness (mm)	31.9 ± 35.0	25.4 ± 26.8*	28.6 ± 28.0	18.2 ± 16.1*	36.3 ± 30.7	25.0 ± 32.1*	<0.05	NS	NS
n	17	17	10	10	23	23			
Fasting PFC (mm)	77.3 ± 30.7	83.7 ± 27.1	79.8 ± 26.9	101.2 ± 29.5	76.2 ± 32.4	93.3 ± 26.2	0.054	NS	NS
n	18	18	13	13	24	24			
AUC desire to eat (mm x min)	5475.4 ± 3482.8	6634.6 ± 4682.0*	5483.7 ± 2856.8	7351.7 ± 4822.4*	4533.1 ± 3827.3	6312.2 ± 4073.2*	<0.05	NS	NS
AUC hunger (mm x min)	5736.7 ± 3986.2	6771.3 ± 4888.4*	5619.8 ± 3083.7	7119.8 ± 4223.3*	4195.0 ± 3610.8	6183.4 ± 3747.8*	<0.05	NS	NS
AUC fullness (mm x min)	16905.0 ± 6312.1	17057.5 ± 5445.3	18252.7 ± 5363.3	16800.6 ± 4770.5	18509.7 ± 5625.5	18632.5 ± 4628.0	NS	NS	NS
AUC PFC (mm x min)	6723.3 ± 4409.4	6701.7 ± 4954.0	7401.4 ± 4129.6	8975.8 ± 4846.5	5967.2 ± 4748.1	6947.5 ±4346.1	NS	NS	NS

Post ≤ 12 months: postmenopausal status ≤ 12 months; Post > 12 months: postmenopausal status > 12 months; Meno: menopausal status; PFC: prospective food consumption; AUC: area under the curve. NS: not significant. Values are mean ± SD. *Significant difference over time within menopausal status ($P < 0.05$ by *post hoc* Tukey's test).

Table 3. Changes in dietary intake before and since menopause onset (year 0)

	Values at menopause		Years before and since menopause onset						
	Mean	s.e.m.	-4	-3	-2	-1	0	+1	+2
n	31		14	20	30	26	31	11	9
7-day food diary									
EI (kcal/day)	1943.7	65.7	105.0 ± 16.2	101.0 ± 20.0	111.0 ± 19.6**	102.5 ± 19.3	100%	110.9 ± 16.8	100.2 ± 16.6
Protein (%)	16.1	0.4	91.2 ± 12.4*	100.0 ± 13.1	101.1 ± 15.9	99.5 ± 16.4	100%	103.7 ± 21.6	105.9 ± 12.5
Carbohydrate (%)	52.7	1.1	97.0 ± 11.7	95.6 ± 8.0*	98.9 ± 11.9	97.7 ±10.5	100%	94.2 ± 11.8	97.1 ± 9.8
Fat (%)	30.6	0.6	108.8 ± 19.4	107.8 ± 13.1*	97.6 ± 24.2	104.2 ± 12.2	100%	105.2 ± 20.8*	100.3 ± 15.4
Protein (g)	76.7	3.1	97.9 ± 19.5	102.2 ± 23.1	112.7 ± 25.3*	103.7 ± 26.3	100%	113.5 ± 23.2	104.5 ± 20.4
Carbohydrate (g)	256.5	11.8	104.6 ± 27.4	99.7 ± 24.0	108.2 ± 25.4	97.7 ±10.5	100%	100.2 ± 21.6	92.9 ± 21.4
Fat (g)	65.3	2.7	119.8 ± 35.4	114.6 ± 31.6	116.0 ± 29.1**	109.9 ± 26.0	100%	118.3 ± 32.9	100.1 ± 20.1
Dietary fiber (g)	24.6	1.7	91.9 ± 29.0	93.3 ± 40.8	118.9 ± 54.6	108.2 ± 45.7	100%	118.5 ± 38.1	120.9 ± 36.4
EF (eating occasions/day)	5.0	0.2	91.5 ± 17.8	94.3 ± 14.7	99.8 ± 20.2	99.7 ± 21.0	100%	110.6 ± 21.4	106.3 ± 15.0
n			17	29	45	40	46	27	13
Buffet-type meal									
EI (kcal)	505.0	31.2	117.6 ± 46.6	113.8 ± 51.2	114.6 ± 43.9*	107.9 ± 58.3	100%	88.6 ± 27.4*	89.8 ± 36.0
Protein (%)	18.6	0.9	106.3 ± 28.1	115.3 ± 47.0	106.9 ± 35.9	107.0 ± 28.6	100%	112.5 ± 25.2*	132.9 ± 46.8*
Carbohydrate (%)	49.7	1.5	103.8 ± 30.5	97.7 ± 23.8	100.5 ± 27.0	103.6 ± 33.9	100%	104.1 ± 25.9	108.1 ± 40.3
Fat (%)	33.4	1.6	98.1 ± 33.6	118.1 ± 61.2	110.1 ± 48.3	106.7 ± 43.1	100%	98.8 ± 46.5	104.1 ± 37.9
Protein (g)	22.3	1.5	124.1 ± 65.6	118.9 ± 40.0*	117.1 ± 43.6*	106.3 ± 40.8	100%	97.9 ± 33.9	110.7 ± 34.5
Carbohydrate (g)	62.8	4.3	116.3 ± 48.6	109.3 ± 51.6	115.8 ± 55.3	104.6 ± 49.4	100%	93.1 ± 39.4	96.8 ± 48.0
Fat (g)	19.2	1.5	121.5 ± 72.1	146.1 ± 128.7	129.9 ± 86.1*	128.2 ± 118.8	100%	88.2 ± 53.2	99.4 ± 69.3
Dietary fiber (g)	5.6	0.4	92.0 ± 48.0	110.6 ± 93.7	123.8 ± 85.4	122.6 ± 100.0	100%	108.5 ± 45.1	105.6 ± 65.9

EI: energy intake; EF: eating frequency. Values are mean ± SD for each year expressed as the percent of the values at year 0 (menopause onset), which was standardized to 100%. Significantly different compared to year 0 (* P<0.05; ** P<0.01).

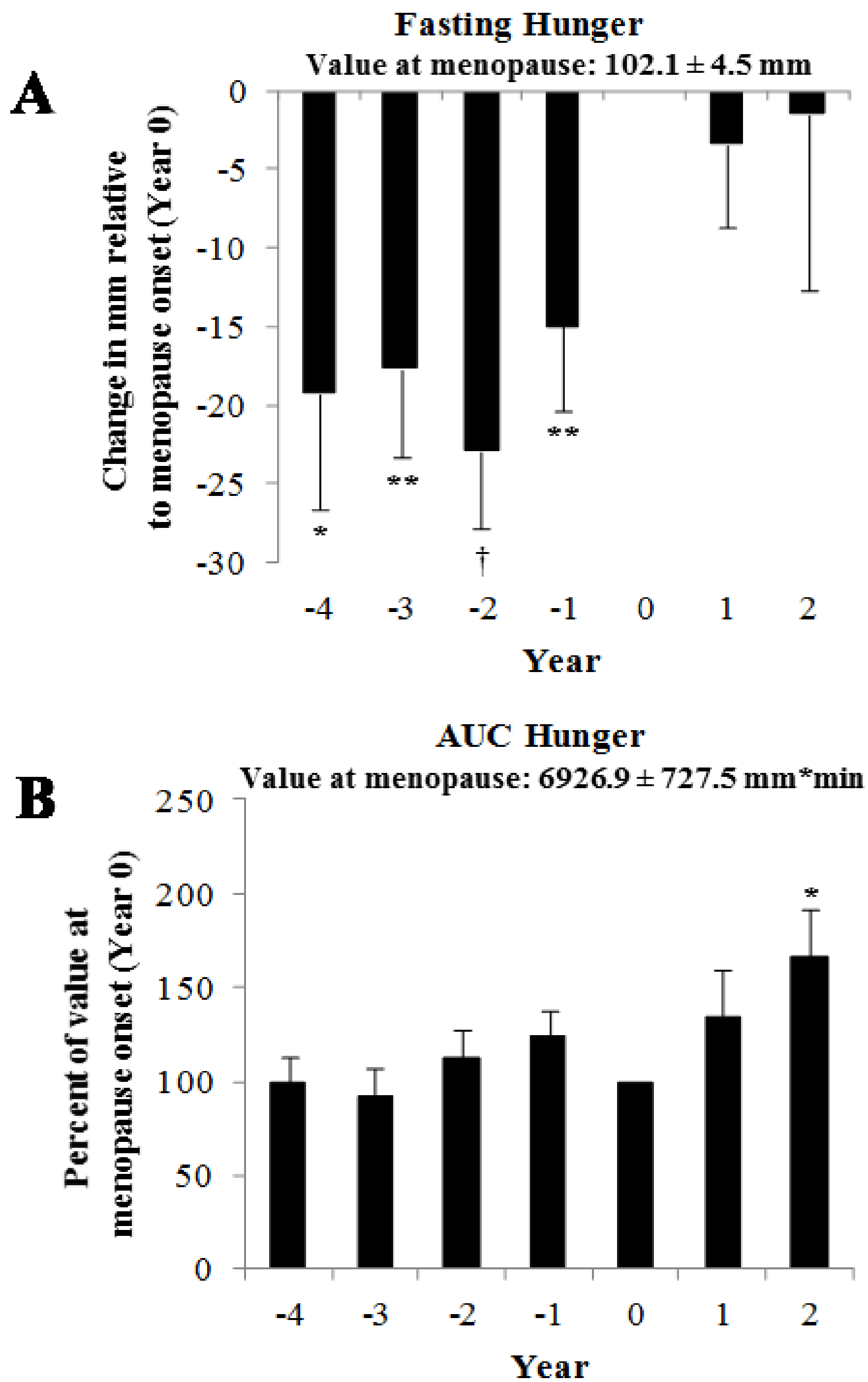

Figure 1. Prospective changes in fasting (A) and area under the curve (AUC) (B) for hunger relative to menopause onset (year 0). Values are mean ± SEM. Values are expressed as the change in mm of the values at year 0 (menopause onset) for fasting hunger. AUC hunger is expressed as the percent of the value at year 0 (menopause onset). Significantly different compared to year 0 (* P<0.05; ** P<0.01; † P<0.001).

CHAPITRE 7

IMPLICATION ET PERSPECTIVES DES TRAVAUX

D'importantes fluctuations du poids corporel peuvent être observées à différentes périodes de la vie d'une femme la rendant ainsi plus vulnérable à une augmentation du risque de développer de l'obésité et des problèmes de santé. La prévalence de l'obésité chez la femme augmente avec l'âge et atteint un niveau maximal entre 45 et 64 ans, période de la vie d'une femme généralement associée à la transition vers la ménopause. Bien que les approches actuelles préconisées dans le traitement de l'obésité produisent des résultats à court terme, le maintien d'une perte de poids à long terme s'avère une tâche difficile pour une majorité de gens. Reconnaissant l'importance de la problématique du contrôle du poids chez la femme, il apparaît important d'étudier certaines dimensions qui s'y rattachent.

L'objectif général de la présente thèse consistait à approfondir nos connaissances relativement aux déterminants physiologiques et comportementaux du poids corporel chez la femme. Les travaux présentés ont contribué à l'avancement des connaissances de plusieurs façons. Ils ont permis d' :

1. Identifier des déterminants physiologiques et comportementaux associés au maintien d'une perte de poids à long terme chez la femme.

2. Observer pour la première fois que la relation négative rapportée dans la littérature entre la fréquence des repas et l'adiposité est influencée par le niveau d'activité physique et la condition cardio-respiratoire.

3. Identifier des changements pouvant survenir au niveau des déterminants physiologiques et comportementaux associés à l'équilibre énergétique pendant la transition ménopausique.

Devant le faible taux de succès à long terme des traitements actuels de perte de poids, il nous apparaissait important de documenter davantage les déterminants pouvant être associés au maintien du poids corporel. L'étude présentée au Chapitre 3 fait état de certains déterminants physiologiques et comportementaux pouvant être associés au maintien d'une perte de poids à long terme chez la femme. Les résultats qui découlent de ces travaux indiquent que les femmes préménopausées ayant réussi à maintenir une perte de poids à long terme dépensent plus de calories par jour à faire de l'activité physique, passent plus de temps à pratiquer de l'activité physique d'intensité vigoureuse, mangent plus souvent, ont un apport alimentaire plus élevé en protéine, consomment moins de glucides, et ont un comportement de restriction alimentaire plus rigide que leurs homologues n'ayant jamais eu de problèmes de poids. Dans l'ensemble, cette étude suggère qu'un apport protéinique plus élevé associée à une pratique régulière d'activité physique et à un contrôle volontaire alimentaire cognitif plus important favoriserait le maintien d'une perte de poids à long terme chez la femme préménopausée.

De nombreuses études épidémiologiques et cliniques ont examiné l'association entre la fréquence des repas et le poids corporel chez les femmes, mais les résultats sont divergents. Certaines études ont observé une relation inverse entre la fréquence des repas et le poids corporel [87, 89-90, 95, 180], tandis que d'autres n'ont trouvé aucune association significative [94, 173]. De plus, la plupart des études interventionnelles n'ont montré aucune influence de la fréquence des repas sur la perte de poids [181-185]. Drummond et al. [95] ont observé, chez les femmes préménopausées, une corrélation positive entre la fréquence des repas et l'apport calorique. Cependant, aucune relation n'a été observée entre le poids corporel et la fréquence des repas. Ces résultats suggèrent la contribution potentielle de facteurs confondants tels que la pratique d'activité physique. La plupart des études qui se sont attardées à la relation entre la fréquence des repas et le poids corporel n'ont toutefois pas considéré la contribution de l'activité physique, qui est un déterminant important du contrôle du poids corporel. Nous avons donc voulu explorer cet aspect plus en profondeur. Nos résultats, présentés au Chapitre 4, suggèrent que la relation négative entre la fréquence des repas et la composition corporelle observée chez des femmes préménopausées, malgré un apport calorique plus élevé, peut s'expliquer par une pratique d'activité physique et une capacité cardio-respiratoire plus élevées. Bien que d'autres études soient nécessaires pour confirmer ces observations, nos résultats portent à croire que, contrairement à ce qui est actuellement recommandé, l'augmentation de la fréquence des repas n'est pas systématiquement associée à un meilleur contrôle du poids corporel et cette relation semble être influencée par le niveau d'activité physique, du moins chez les femmes préménopausées. Toutefois, il a été suggéré que tant que l'apport alimentaire n'est pas supérieur à la dépense énergétique et que les individus ne mangent que lorsqu'ils ont faim, manger plusieurs petits repas dans la journée peut être utile pour certains [186]. Cependant, nos résultats suggèrent qu'il faudrait être prudent avant de prescrire une telle approche alimentaire à la population générale.

Compte tenu du fait qu'un gain de poids et des changements dans la composition corporelle peuvent survenir durant la période de la transition ménopausique et que cela peut avoir des répercussions sur la santé des femmes [14-19], il nous apparaissait important de mesurer l'impact de la transition ménopausique sur les déterminants physiologiques et comportementaux associés à l'équilibre énergétique. Les résultats des Chapitres 5 et 6 viennent mettre en évidence le fait que la transition ménopausique est accompagnée d'une diminution de la dépense énergétique, principalement caractérisée par une diminution de la pratique d'activité physique, de l'adoption d'un mode de vie plus sédentaire et d'une augmentation de l'appétit. Cette étude illustre pour la première fois l'augmentation de l'appétit qui peut survenir pendant la transition ménopausique. Cependant, bien qu'une augmentation de l'appétit puisse influencer positivement la prise alimentaire, nous n'avons pas observé d'augmentation de l'apport calorique. Par conséquent, l'absence de gain de poids noté pendant la transition ménopausique pourrait s'expliquer par une réduction de l'apport calorique, ce qui pourrait compenser l'effet de la diminution de la pratique d'activité physique sur l'équilibre énergétique. Les résultats de cette étude suggèrent donc que les femmes qui ne diminuent pas leur apport alimentaire ou n'augmentent pas leur pratique d'activité physique pour compenser le déclin au niveau de la dépense énergétique et l'augmentation de l'appétit associés à la ménopause pourraient être plus susceptibles au gain de poids pendant la transition ménopausique ainsi qu'au cours des années en post-ménopause. Toutefois, il est à noter que notre étude ne nous permet pas de conclure en ce sens, puisque les femmes dans l'ensemble, n'ont pas vu leur poids augmenter de façon significative au cours de ce suivi de 5 ans [19].

De telles observations soutiennent qu'il est possible de prévenir la prise de poids durant la transition ménopausique. La prévention du gain de poids à tout âge exige que l'apport énergétique ne dépasse pas la dépense énergétique. Cependant, bien que cela paraisse simple en théorie, la transition ménopausique entraîne des changements physiologiques et hormonaux qui rendent le maintien du poids plus ardu. Le maintien du poids représente un défi pour plusieurs femmes. Or, selon plusieurs études, des changements de comportement, en particulier une augmentation de la pratique d'activité physique, permettraient d'atténuer ou de prévenir le gain de poids et les changements de composition corporelle observés durant la transition ménopausique [154, 187]. En effet, il semble que la pratique régulière d'activité physique, à intensité modérée ou élevée, contribue à atténuer ou à prévenir le gain de poids, la diminution de la masse musculaire et l'augmentation de la masse adipeuse totale et abdominale [148, 154, 188]. Il a également été rapporté que les femmes physiquement actives ont tendance à prendre moins de poids que les femmes sédentaires pendant la transition ménopausique [189]. L'activité physique pourrait donc être un élément important à considérer durant cette période de la vie d'une femme.

Compte tenu de tous les éléments mentionnés précédemment, une pratique régulière d'activité physique et une saine alimentation devraient être adoptées, et ce, dès le début de la transition ménopausique, voire avant puisqu'il a été observé que 30% des femmes entrent en ménopause avec un problème d'embonpoint [20]. Les femmes qui amorcent la période de la transition ménopausique devraient être informées des stratégies comportementales qui les aideront à assurer un meilleur contrôle de leur poids corporel. Le plus important n'est pas le poids, mais bien le fait de manger sainement et de faire régulièrement de l'activité physique. De plus, un mode de vie sain contribue à réduire l'intensité des symptômes vasomoteurs de la ménopause, améliore la santé cardiovasculaire et apporte une certaine protection contre plusieurs problèmes de santé [154, 190-196]. Une gestion précoce du poids corporel chez les femmes à l'approche de la ménopause est donc souhaitable.

Il importe également de discuter des forces et de certaines limites des études présentées dans cette thèse. Tout d'abord, le fait que toutes les études qui ont fait l'objet de cette thèse soient issues du même groupe de femmes (non-obèses selon l'IMC et en santé) constitue la principale limite de ces travaux. Par conséquent, les résultats ne peuvent être généralisés à l'ensemble population. Cependant, il est important de mentionner que selon l'Enquête canadienne sur les mesures de la santé (ECMS) de 2007-2009 publiée par Statistique Canada 76% des femmes canadiennes âgées entre 40 et 59 ans présentent un IMC entre 20 et 29 kg/m^2 [32]. Un autre facteur qui restreint l'extrapolation de certains résultats est le faible échantillon de sujets dans le projet WiLMa (n=44), ce qui peut limiter la validité externe des résultats. Il serait donc prudent de reproduire ces résultats chez d'autres populations (femmes avec un plus large éventail d'adiposité) et avec des échantillons plus considérables avant de pouvoir généraliser ces résultats à l'ensemble des femmes. Néanmoins, les travaux de cette thèse présentent également des forces. Ils se différencient des autres études par la méthode et les mesures d'évaluation utilisées. En effet, peu d'études longitudinales ont été menées sur les déterminants physiologiques et comportementaux associés à la transition ménopausique. De plus, l'utilisation de la mesure étalon-or pour évaluer la composition corporelle et de mesures d'évaluation objectives de la dépense énergétique, de l'apport et des comportements alimentaires ainsi que de l'appétit n'est pas courante et a permis de combler une lacune importante au niveau des connaissances, en regard de ces phénotypes, dans ce domaine de recherche.

Il serait tout à fait utopique de croire que les travaux de la présente thèse aient permis de répondre à l'ensemble des questions de recherche touchant les déterminants du poids corporel chez la femme. En réalisant ces deux études, nous avons plutôt pris conscience de toute la complexité qui émerge de ce domaine de recherche. Les résultats présentés dans cette thèse ont mis en lumière d'autres questions et hypothèses de recherche qui demeurent toujours sans réponse, ce qui nous incite à nous pencher sur les perspectives de recherches futures. Pourquoi les femmes diminuent-elles leur pratique d'activité physique et leur apport alimentaire pendant la transition ménopausique? Est-ce que la présence et l'intensité des symptômes vasomoteurs lors de la transition ménopausique peut influencer la pratique d'activité physique et/ou l'apport calorique des femmes? Est-ce que le fait d'être plus préoccupée par les changements de composition corporelle pouvant survenir pendant la transition ménopausique amène les femmes à modifier volontairement leurs habitudes de vie pour ainsi éviter la prise de poids? Bien qu'aucune prise de poids significative n'ait été observée dans le cadre de l'étude MONET [19], la diminution de la dépense énergétique de 200 kcal ainsi que l'augmentation de l'appétit pourraient-elles avoir un impact négatif sur le contrôle du poids à long terme des femmes post-ménopausées? Voilà des questionnements soulevés par les résultats présentés dans cette thèse qui demeurent actuellement sans réponse. Dans le cadre d'études éventuelles, il serait tout d'abord intéressant d'explorer, à l'aide de groupe de discussion, les raisons sous-jacentes aux changements comportementaux observés pendant la transition ménopausique dans le projet MONET. De plus, la réalisation d'études longitudinales évaluant l'impact à long terme des changements survenus pendant la transition ménopausique au niveau des déterminants associés à l'équilibre énergétique sur le poids, la composition corporelle et la santé des femmes post-ménopausées pourrait constituer une autre avenue de recherche intéressante. Concernant les déterminants du maintien de poids, il pourrait être intéressant d'examiner les déterminants psychosociaux ainsi que de comparer les femmes ayant eu du succès avec le maintien d'une perte de poids à long terme à des femmes obèses n'ayant jamais réussi à maintenir leur perte de poids, ce qui n'a pas été exploré dans cette thèse. Tel que discuté dans la problématique de cette thèse, les problèmes reliés au poids découlent de multiples facteurs biopsychosociaux, environnementaux et comportementaux. Il est donc important de tenir compte de l'ensemble de ces facteurs pour ainsi pouvoir agir plus efficacement. De plus, les résultats du projet WiLMa (Chapitre 3) pourraient servir de tremplin à l'élaboration d'études à plus grande échelle ainsi qu'à la création d'un registre canadien sur les déterminants du maintien de poids tel que le *NWCR* aux États-Unis. La création d'un tel registre est importante considérant que le contrôle du poids corporel est influencé par les caractéristiques sociales, culturelles et environnementales de la société dans laquelle vivent les individus [3, 197-198].

De plus, la mise sur pied d’un registre contenant un meilleur phénotypage des facteurs biopsychosociaux, environnementaux et comportementaux pouvant influencer le contrôle du poids corporel est souhaitable.

En somme, l’intégration des résultats présentés dans cette thèse fait ressortir l’importance de l’adoption d’un mode de vie actif dans le contrôle du poids corporel chez la femme. Cependant, l’adoption d’un tel mode de vie peut parfois s’avérer difficile. En effet, au Canada, plus des deux tiers des femmes ont un mode de vie sédentaire [99]. Pour que les gens puissent être actifs dans leur quotidien et choisir des aliments sains, et ainsi assurer un meilleur contrôle du poids corporel, ils doivent absolument vivre dans un environnement propice à ces choix et bénéficier du soutien de leur communauté. Un tel constat souligne l'importance de soutenir les individus dans leur démarche de changement par la mise en place de politiques et la création d’environnements et de conditions favorables à l’adoption et au maintien de saines habitudes de vie. Au Québec, la réponse gouvernementale aux problèmes de poids s’inscrit dans le plan d’action ministériel intitulé « Investir pour l’avenir - Plan d’action gouvernemental de promotion des saines habitudes de vie et de prévention des problèmes reliés au poids 2006-2012 » [160]. Ce plan d’action fait état des orientations du gouvernement et des interventions à mettre en place dans le but de favoriser l'adoption de saines habitudes de vie dans une optique de prévention et ce, tant chez les individus que dans la société. Il ne reste plus qu’à poursuivre sur cette lancée et à ne pas oublier que la responsabilité d’une population en santé est l’affaire de tous.

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ANNEXE A

LA FRÉQUENCE DES REPAS ET LE POIDS CORPOREL

Karine Duval et Éric Doucet

Le chapitre de livre composant cette annexe est intitulé :

« Eating frequency and anthropometry. »

(*Handbook of Anthropometry: Physical Measures of Human Form in Health and Disease* 2012; 2837-2871)

Contribution des auteurs :

Karine Duval a effectué la revue de la littérature et la rédaction de ce chapitre de livre. Éric Doucet a participé à la révision du chapitre de livre.

RÉSUMÉ

Il existe une croyance que manger entre les repas, ou collationner, conduit à une augmentation du poids et de l'obésité. Les conseils en santé publique pour le contrôle du poids corporel suggèrent souvent d'éviter les collations entre les repas afin de ne pas augmenter l'apport énergétique total. Cependant, les résultats de recherche actuellement disponibles sur l'effet que la fréquence des repas peut avoir sur le poids corporel sont divergents. Certaines études menées chez les adultes et les enfants ont observé une relation inverse entre la fréquence des repas et le poids corporel, tandis que d'autres n'ont trouvé aucune association significative. Plusieurs différences méthodologiques ont été proposées pour expliquer les différences observées entre les études : définitions différentes de la fréquence des repas; sous-estimation de l'apport alimentaire, en particulier chez les obèses; différentes méthodes d'évaluation de l'apport alimentaire et de la composition corporelle et le fait que de nombreuses études ne prennent pas en compte les facteurs liés à la dépense énergétique, tout particulièrement l'activité physique. Malgré les résultats divergents, la fréquence des repas semble être associée à un poids corporel inférieur chez les hommes. Chez les femmes, de nombreuses études n'ont trouvé aucune association ou une corrélation négative entre la fréquence des repas et l'adiposité, malgré un apport énergétique plus élevé. Il a été suggéré qu'une plus grande fréquence des repas pourrait très bien être un marqueur d'un mode de vie actif. L'impact de la fréquence des repas sur la perte de poids au cours d'une restriction calorique et sur la dépense énergétique est quant à elle plus concluante. Aucune différence au niveau de la dépense énergétique totale n'a été documentée en fonction de la fréquence des repas et la perte de poids ne semble pas être facilitée par une fréquence des repas plus élevée. D'autres études à devis longitudinal incluant un plus grand nombre de sujets et utilisant des méthodes d'évaluation appropriées sont donc nécessaires afin d'éclaircir la relation entre la fréquence des repas et l'adiposité.

Chapter 178
Eating Frequency and Anthropometry

Karine Duval and Éric Doucet

Abstract There is a belief that eating between meals, or snacking, leads to increases in weight and obesity. Public health advice for body weight control often suggests avoiding snacks between meals in order to not increase total energy intake. However, available results from research on the influence of eating frequency on body weight status are equivocal. Studies in both adults and children have either failed to find a significant relationship between eating frequency and adiposity, or have found an inverse relationship. Several methodological discrepancies have been proposed to explain some differences observed between studies or the lack of such a relationship: various definitions of eating occasions, under-reporting of food intake, especially among the obese, various methods of assessing food intake and body composition, and the fact that many studies did not take into account factors related to energy expenditure, especially physical activity. Despite the inconclusive results, eating frequency seems to be related with leanness in men. In women, many studies found no association or negative correlation between eating frequency and adiposity, despite a higher energy intake. It was suggested that a higher eating frequency could very well be a marker of a physically active lifestyle, at least in leaner individuals. The impact of eating frequency on weight loss during energy restriction and on energy expenditure is more conclusive. No difference in total energy expenditure has been documented as a function of daily eating occasions and weight loss does not seem to be facilitated by high meal frequency. There is a need to examine the relationship between eating frequency and adiposity using longer-term studies with sufficiently large sample sizes and using adequate and standardized methodologies.

Abbreviations

BMI	Body mass index
BMR	Basal metabolic rate
DLW	Doubly labeled water
EE	Energy expenditure
EF	Eating frequency
EI	Energy intake

V.R. Preedy (ed.), *Handbook of Anthropometry: Physical Measures of Human Form in Health and Disease*, DOI 10.1007/978-1-4419-1788-1_178,

GIP	Glucose-dependent Insulinotropic Polypeptide
HMG-CoA	Hydroxymethylglutaryl-CoA
LDL	Low density lipoprotein
PAEE	Physical activity energy expenditure
PAL	Physical activity level
REE	Resting energy expenditure
RMR	Resting metabolic rate
TEE	Total energy expenditure
TEF	Thermic effect of food
VO_{2peak}	Peak oxygen uptake

178.1 Introduction

Over the last few decades, the prevalence of obesity has rapidly increased in many countries around the world and reached now epidemic proportions (Hedley et al. 2004). The dietary pattern has changed substantially over the years (Briefel and Johnson 2004). The environment we live in has become ‘obesogenic’ (obesity-promoting). Food is constantly available and in practically unlimited amounts, which can lead to excessive energy intake (EI) and therefore positive energy balance (WHO 2002). Changes in dietary habits and physical activity have also been implicated as potential causes of obesity (WHO 2002).

Total EI has increased over the past 20–30 years (Nielsen et al. 2002). Using a nationally representative data from adults, Kant and Graubard looked at the change in eating frequency (EF) of American men and women over a 30-year period using data collected in the National Health and Nutrition Examination Surveys (NHANES) I (1971–1975), II (1976–1980), III (1988–1994), 1999–2000, and 2001–2002 (Kant and Graubard 2006). Over the time period, the reported number of eating occasions increased slightly in women from 4.90 in 1971–1975 to 5.04 in 1999–2002 (see Fig. 178.1). Cutler et al. have also shown an increasing in EF for both men and women between 1970 and 1990 (see Fig. 178.2a) (Cutler et al. 2003). During this time period, the increase in EI seems to be related with the increased EF and the energy consumed during snacks (see Fig. 178.2b, c). This change in eating pattern is probably a result of the increased availability of snack foods.

Studies have suggested that several eating behaviors, such as EF, the temporal distribution of eating events across the day, breakfast skipping, portion size, and the frequency of meals eaten away from home, may have an influence on body-weight control (Seagle et al. 2009). Research on the possible body weight and health benefits of EF started from observational and interventional studies in the 1960s, suggesting an inverse relationship between EF and adiposity (Fabry et al. 1964; Fabry et al. 1966).

When to eat and how often? Is it preferable to eat multiple small meals daily? These questions are frequently posed by persons who would like to lose or maintain their weight, and most health professionals would like to be able to answer it. However, they are not easy questions to answer. As will be discussed throughout this chapter, the impact of EF on body weight is not simple and implies more than one aspect. A great deal research has investigated the relationship between eating pattern and body-weight status (Bellisle et al. 1997). However, no clear consensus on the optimal number of daily eating occasions to facilitate weight management has emerged. This book chapter reviews the literature on EF with respect to energy balance and body-weight control.

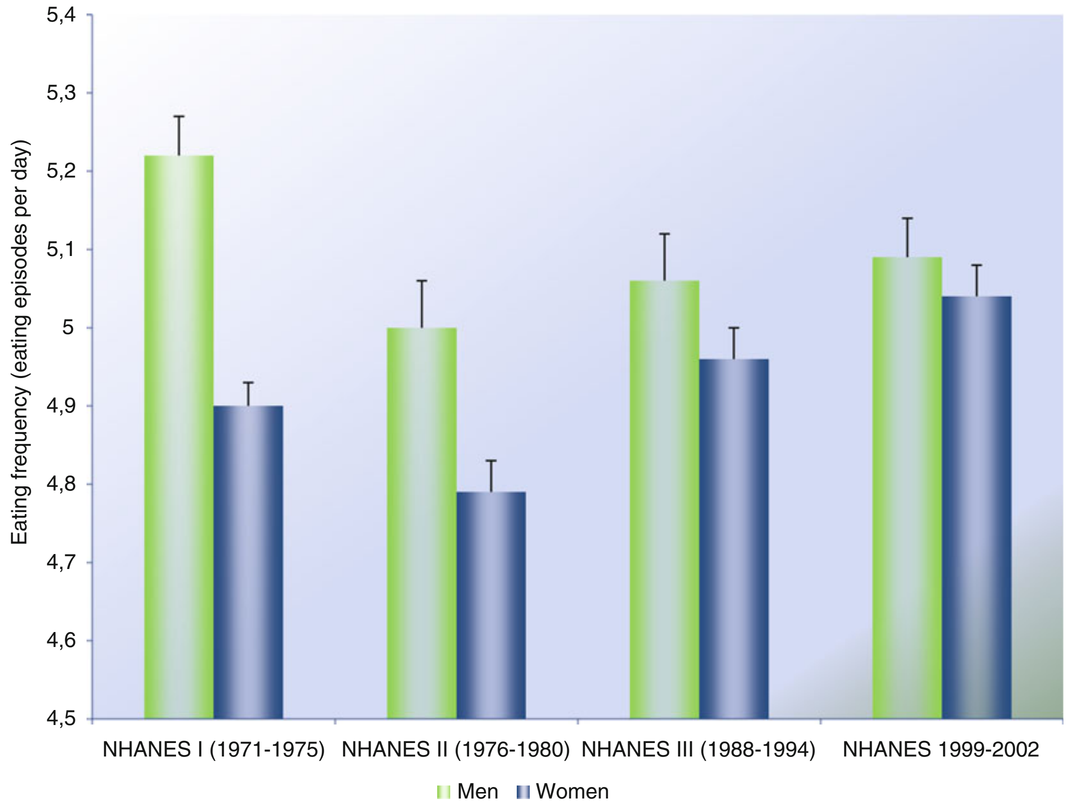


Fig. 178.1 Secular trends of eating frequency from National Health and Nutrition Examination Surveys (NHANES): NHANES 1971–1975 to NHANES 1999–2002. According to data collected in the National Health and Nutrition Examination Surveys from 1971–1975 to 1999–2002, this figure shows that EF of American adults, measured by 24-h recall, has increased significantly in women, but not in men during this time period. Results are presented as *mean* ± *SD*, *n* = NHANES I (men: 4,931; women: 5,060); NHANES II (men: 4,877; women: 5,241); NHANES III (men: 5,889; women 6,153); and NHANES 1999–2002 (men: 3,186; women: 3,211) (Data from Kant and Graubard 2006)

178.2 Part I: Methodological Aspects of Eating Frequency

178.2.1 Definitions of Key Eating-Frequency Terms

Part of the difficulty in identifying implications of eating more frequently is related to the lack of standardized definitions of key terms, such as eating occasions, meals and snacks (Drummond et al. 1996; Gatenby 1997; Gregori and Maffeis 2007). There have been several suggestions for these definitions, and each one was based on different cultural, biological, and empirical parameters of measurement (Drummond et al. 1996; Gibney and Wolever 1997). The type of definition used to describe key EF terms may significantly influence the outcomes and interpretation of results from different studies (Gatenby 1997; McBride et al. 1990). To date, no one definition has been universally accepted to categorize EF in the scientific literature. Comparisons among studies are even more difficult, as definitions of these terms were not always adequately reported in the literature.

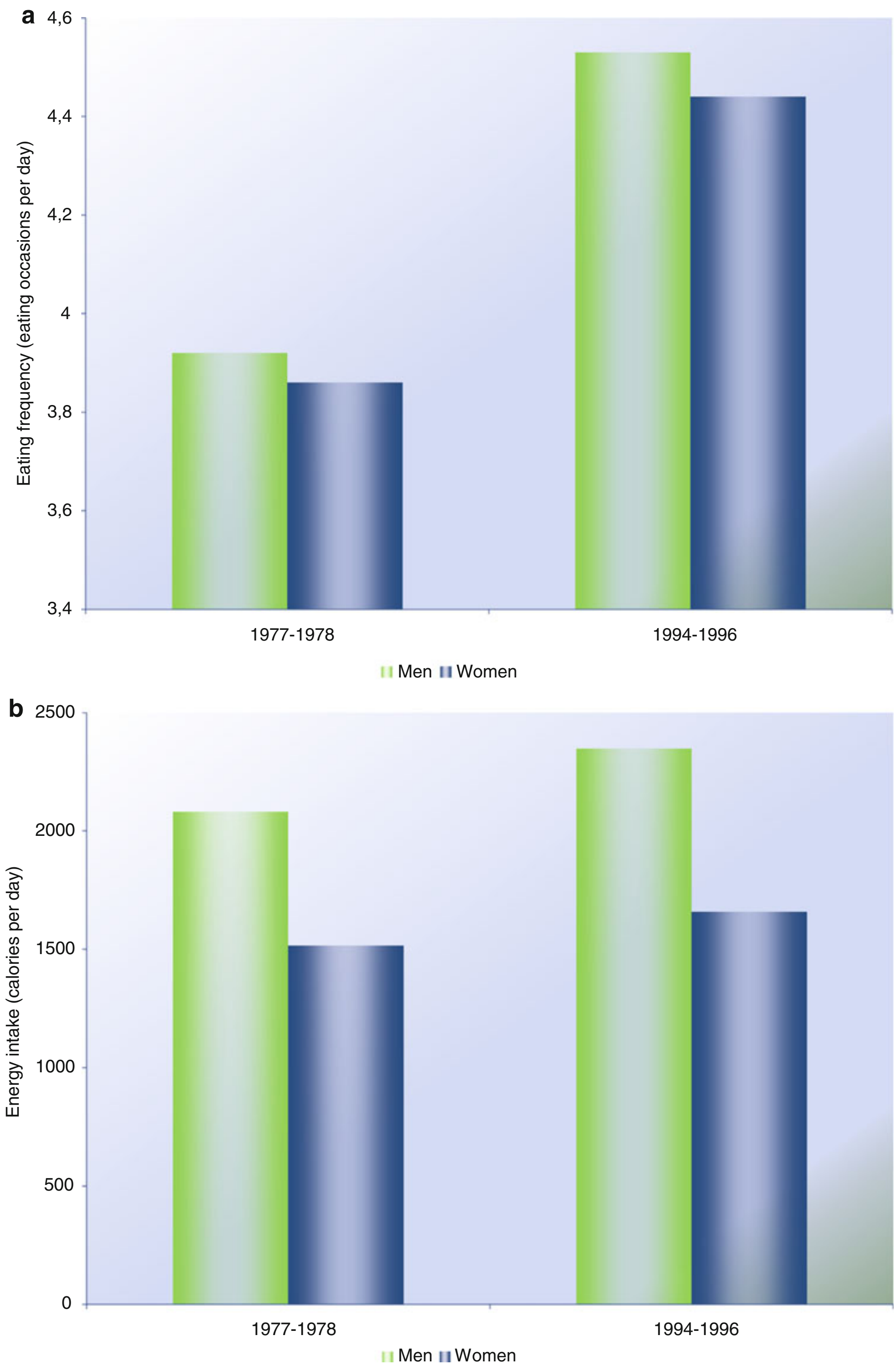


Fig. 178.2 (**a**) Secular trends of eating frequency among US adults from 1977–1978 and 1994–1996. According to cross-sectional data from the Continuing Surveys of Food Intake by Individuals (CSFII), this figure shows that EF has increased among American adults between 1977–1978 and 1994–1996 for both men and women. Results presented are means (Data from Cutler et al. 2003) (**b**) Secular trends of energy intake among US adults from 1977–1978 and 1994–1996. According to cross-sectional data from the Continuing Surveys of Food Intake by Individuals (CSFII), this figure shows that EI has increased among American adults between 1977–1978 and 1994–1996 for both men and women.

c

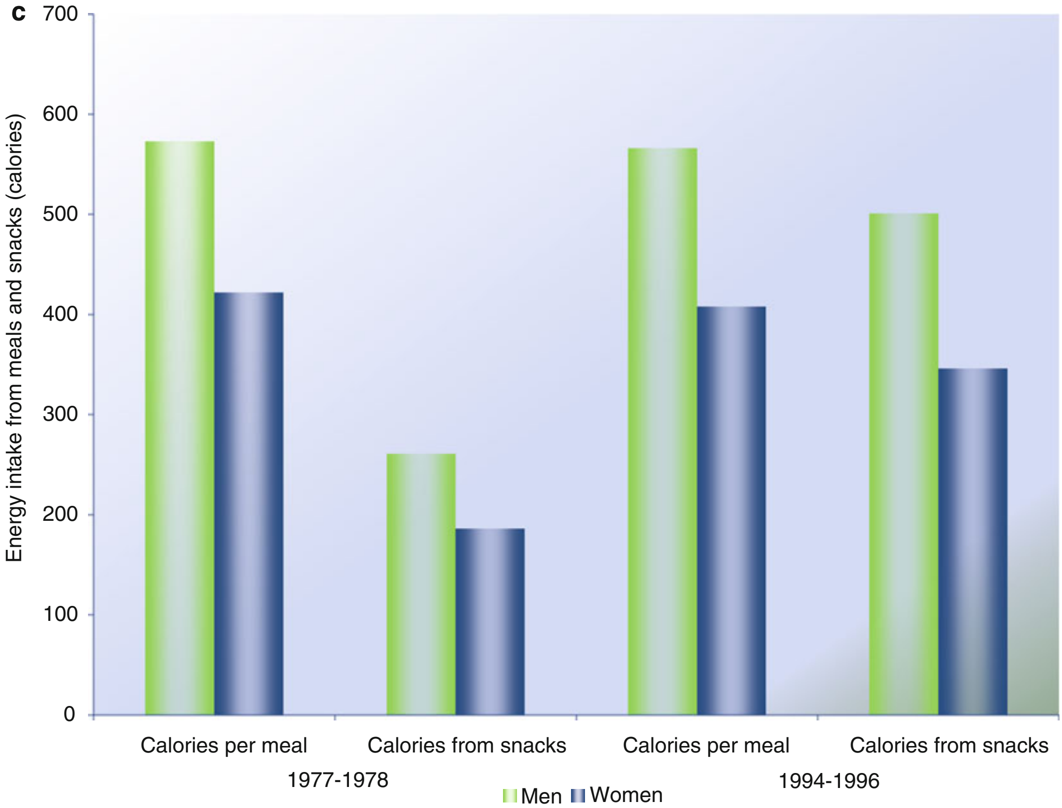


Fig. 178.2 (continued) Results presented are means (Data from Cutler et al. 2003) (**c**) Secular trends of energy intake from meals and snacks among U.S. adults from 1977–1978 and 1994–1996. According to cross-sectional data from the Continuing Surveys of Food Intake by Individuals (CSFII), this figure shows that most of the increase in EI is from calories consumed during snacks. Indeed, the energy consumed per meal has decreased (especially at dinnertime), while the energy consumed during snacks has increased by 90% among men and 112% among women between 1977–1978 and 1994–1996. Results presented are means (Data from Cutler et al. 2003)

178.2.1.1 Eating Frequency

Usually, low EF has been defined as "gorging" and high EF as "nibbling" (Berteus Forslund et al. 2002). However, there is no agreement about the number of meals required to be classified as frequent or non-frequent eater. In the literature, there is a wide range in the number of eating episodes used to describe "nibbling" (3–17 meals/snacks per day) and "gorging" (1–3 meals per day) (Berteus Forslund et al. 2002). Eating frequency is usually referred by a number of eating occasions, eating events or eating episodes per day. Two types of definition are normally reported to categorize EF: (1) predefined eating periods and (2) time interval between two eating occasions. Most studies that have been conducted until more recently used the predefined eating periods' definition to analyze EF (Summerbell et al. 1996; Dreon et al. 1988; Barba et al. 2006). In a study by Summerbell et al. (1996), daily food intake was divided into six eating periods (breakfast, mid-morning snacks, lunch, mid-afternoon snacks, evening meal, and evening snacks), which were defined as "meals" or "snacks." In this study, the maximum number of eating occasions was six. Such an approach may not permit an adequate analysis of EF due to inappropriate and insufficiently detailed information and may mask the actual EF (Gatenby 1997). The 'time interval' definition for calculating the total number of eating occasions is now mostly used by the investigators (Drummond et al. 1998; Duval et al. 2008a; Yannakoulia et al. 2007; Ruidavets et al. 2002). The time interval between two eating occasions is normally ranged between 15 and 60 min. Drummond et al. (1998) defined an eating occasion as any occasion when food was consumed. If two eating occasions occurred in ≤15 min, both events were counted as a single occasion. Ruidavets et al. (2002) used a similar definition but with a longer time interval between two eating periods (60 min). Gibney and Wolever (1997) added energy content to this definition, which classifies an eating occasion as an event that provides at least 50 kcal (or 210 kJ) with a minimum time interval between occasions of at least 15 min. This type of definition allows to include all eating events in the calculation of EF and avoid the ambiguities of classifying eating events as either "meals" or "snacks," which, as mentioned earlier, can mask the number of actual eating occasions, especially when EF is high (Gatenby 1997).

178.2.1.2 Snack and Meal

The majority of investigators used quantitative definitions to describe what constitutes a "meal" and a "snack." These definitions were based mainly on the criteria of time of consumption and/or nutrient composition of the eating occasions (Gatenby 1997). Meals are generally described as one of the main eating occasions of the day, normally occurring in the morning (breakfast), mid-day (lunch), or evening (dinner) (Gatenby 1997; de Graaf 2006). Snacks refer to the other eating episodes consumed between meals, which are generally smaller and less structured than meals (de Graaf 2006; Gatenby 1997). However, it is difficult to obtain one specific universally accepted definition due to the problems inherent in individual perception of what constitutes a snack as opposed to a meal (Drummond et al. 1996).

Many criteria can be used to make a distinction between "meal" and "snack" (Gregori and Maffeis 2007; Vitapole 2003).

1. **Timing**
   Foods consumed at a specific period of time, for example, between 8:00 and 10:00 AM (breakfast), between 12:00 and 2:00 PM (lunch), and between 6:00 and 8:00 PM (dinner), are considered as meals. Anything else consumed between meals is thus considered as a snack (Gregori and Maffeis 2007). This criterion has to be used with caution because the time for a specific eating period may not always be the same for everyone depending on the work schedule, cultural aspects, or religious beliefs.
2. **Interval between adjacent eating episodes**
   It was observed that larger-size meals, as compared to snacks, are followed by longer periods of no eating (Bellisle et al. 2003).
3. **Social considerations**
   This criterion refers to the food consumed in the company of others or alone. Rotenberg used a social definition of eating occasions: the presence or absence of fellow diners (Rotenberg 1981). With this definition, a "meal" was defined as a planned social interaction centered on food, whereas a "snack" was identified as an eating event conducted individually.
4. **Nutrient composition**
   The nutrient-composition criterion of a meal or a snack includes the energy content and/or the type of food. Snacks are clearly different from meals. They differ in size (meals are about twice as large as snacks) and nutritional content (snack have a relatively high CHO content) (Drummond et al. 1996; Summerbell et al. 1996). Meals bring more energy and nutrient diversity than snacks.

Bernstein et al., studying the eating patterns of free-living subjects without time cues, defined "meal" as eating episodes of greater than 375 kJ (Bernstein et al. 1981).

5. **Hunger criterion**
   This criterion refers to the food consumed in either a hungry state or a non-hungry state. It was reported that a meal occurs usually when food is consumed in a state of hunger (Bellisle et al. 2003).

The definition of a meal or a snack should be based on more than one criterion in order to avoid ambiguities about what constitutes a meal and what constitutes a snack. As an example, a beverage with an apple consumed at 12:30 PM might be regarded as a snack or a meal depending on whether the definition refers to time of day or food type as a means of classification.

The problem with inconsistent definitions of eating occasion, meals, and snacks have been discussed earlier (Drummond et al. 1996; Gatenby 1997), and there is agreement on the need to clarify the terminology in order to be able to accurately investigate the role of EF on health (Gibney and Wolever 1997). A more consistent approach to the definition of eating occasions would facilitate appropriate interpretation of the available literature and future research. Even in the absence of a clear consensus, a clear description of what is considered to constitute an eating episode should always be provided in manuscripts investigating the topic of EF (Gregori and Maffeis 2007).

178.2.2 How to Measure Eating Frequency?

The methods used to assess food intake is worth taking into account when measuring EF. Various dietary-assessment methods have been developed for measuring food intake, and they have been extensively reviewed (Bingham 1987; Block 1982). Dietary methods most frequently used in research can be divided into three categories: (1) recall of actual food eaten, generally limited to the previous 24 h (24-h diet recall); (2) retrospective questionnaires or histories of the usual diet (food-frequency questionnaire or diet history); and (3) prospective diet records, usually for 3, 4, or 7 days, which are weighed or quantified by household measures, such as cups and spoons (Black et al. 1991; Barrett-Connor 1991; Block 1982; Livingstone 1995). Dietary recalls and food records are mostly used in EF studies. This can be explained by the fact that these two methods allow to determine more easily each eating occasion, as they provide information about the actual diet.

178.2.2.1 The 24-h Diet Recall

The 24-h diet-recall method is designed to quantitatively collect all foods consumed during the previous 24 h (Barrett-Connor 1991). This method typically involves face-to-face interview, although it may be conducted by telephone (Smith 1993; Block 1982). This technique demands high interviewing skills and can be affected by interaction between the interviewer and the interviewee and the subjective interpretation of questions and answers. Recall methods are prone to error of memory. However, the short-term memory required in the 24-h diet recall reduced the risk of errors. A 24-h diet recall obtained by a trained dietician takes normally around 30–60 min and can provide accurate quantitative information on recent intake. However, a single day of food intake may not be representative of habitual diet (Barrett-Connor 1991; Block 1982). Indeed, considering day-to-day variation in the food intake, multiple 24-h recalls are required to describe an individual's diet (Bingham 1987; Beaton et al. 1979; Basiotis et al. 1987).

178.2.2.2 Food Record or Diary

The food-record method provides a measure of current intake and involves a detailed record of all food consumed and measurements of portion size. Subjects have to record all food items consumed at the time of eating for a specified period, usually 3, 4, or 7 days. Subjects may estimate the portions eaten either by direct weighing (weighed food record) or by using household measures, such as cups or spoons (food diary). The accuracy of recording methods is based on the assumption that the usual dietary pattern is not changed because it is being recorded. Writing down everything they eat can be burdensome and time consuming for some subjects. Consequently, this method is often associated with poor compliance and an alteration of the diet and the dietary reporting during the recording period (Barrett-Connor 1991). In addition, recording intakes requires some literacy, which may limit the study to better-educated subjects. Nevertheless, the food record has often been considered the most accurate and precise method of dietary assessment (Barrett-Connor 1991). Whybrow et al. have shown that record of food intake for a period longer than 3 days and ideally 7 days is preferable (Whybrow et al. 2008). Seven-day food records are generally regarded as providing the best compromise between accurate data, investigator workload, and subject compliance (Black et al. 1991), although it is recognized that longer periods are needed to obtain precise measures of the habitual intakes of individuals (Basiotis et al. 1987; Beaton et al. 1979; Bingham 1987). However, for most studies in a free-living situation, it is unrealistic to collect dietary information for more than 3–7 days.

Data on the validity of recalls and records specifically for estimating EF are unavailable for the moment. Thus, the degree to which these methods accurately estimate the number of eating occasions is unclear. However, Longnecker et al. found that the day-to-day variation in a person's EF is larger than between-subject variation, which suggests that data from multiple days of a food diary are needed to measure a person's EF with precision (Longnecker et al. 1997). It has also been suggested that the use of a 7-day food diary provides a more accurate measurement of EI and is more representative of usual intake than is the use of food-frequency questionnaires or dietary recall (Block 1982).

The measurement of food intake is one of the hardest tasks in studies dealing with some forms of dietary assessments. None of the dietary-assessment methods is a priori better. The choice of the method will be based on the design and objectives of the study and the nature of the information required. Even when an appropriate method is selected, it remains difficult to acquire accurate data from food reporting (Livingstone 1995; Westerterp and Goris 2002).

178.2.2.3 Accuracy of Diet Reporting

During the past several years, there has been considerable discussion about the relevance of the dietary-survey methodologies, with much of this debate focused on their validity. A valid dietary report is one that measures the true intake, that is, all food consumed on specified days without exerting an influence on the choice of food and drinks consumed, during the period of study (Livingstone 1995). Accurate assessments of dietary intake are a prerequisite for assessing the relationship between diet and body-weight status (Gatenby 1997). Unfortunately, most of the methods for assessing dietary intakes have rarely been fully and independently validated because of the absence of accurate techniques to verify dietary-survey methodology.

Previous research in dietary assessment has indicated persistent errors in self-reported EI (Bailey et al. 2007; Livingstone 1995). The widespread occurrence of under-reporting of EI has been exposed by the introduction of the doubly labeled water (DLW) method for measuring total daily energy expenditure (TEE) (McCrory et al. 2002). The presence of error in self-reported dietary data may attenuate or exaggerate associations between diet and weight status (Lissner et al. 1998). Most of the bias which appears when dietary intake is measured is mostly due to under-reporting (Livingstone 1995). When asked, people in general tend to underestimate the amount of food they eat. The only known method of gathering information on habitual diet intake is to ask subjects to supply this information themselves. Every self-report modality is prone to the problem of under-reporting. The problem of dietary under-reporting has been addressed in a number of articles as a major limitation in dietary assessments, and it is not easily overcome (Gatenby 1997; Garrow and Summerbell 1995; Bellisle et al. 1997). Under-reporting has been observed to vary from 10% to 50% (Livingstone 1995; Macdiarmid and Blundell 1997). Under-reporting of habitual intake can result from under-recording, under-eating, or a combination of both (McCrory et al. 2002; Bingham 1991). Under-recording refers to the failure to record all items and/or amounts of food consumed (McCrory et al. 2002). Under-eating corresponds rather to eating less than usual or than is required to maintain body weight (McCrory et al. 2002). A number of methodological and behavioral factors can generate these two biases. They include feeling embarrassed or guilty about recording specific foods or amounts, mostly foods perceived as "unhealthy," inability to estimate portion sizes accurately in non-weighed recording and recall methods, memory lapses, conscious or subconscious omissions to simplify the recording due to irritation and inconvenience in reporting, being more conscious of what they eat and, finally, using the study period as an opportunity to start dieting and to lose weight (Livingstone 1995). It has been documented that people admit that they would change their behavior when asked to complete dietary records (Mela and Aaron 1997).

Reporting errors have been associated with a number of different subject characteristics, which was reviewed by Macdiarmid and Blundell (1997). Certain sub-populations are more likely to under-report their food intake than others, in particular the obese, the post-obese, the overweight, and the diet-restrained subjects (Livingstone and Black 2003; Heitmann and Lissner 1995). Westerterp and Goris (2002) have shown that percentage of under-reporting in normal-weight subjects varies from 0% to 25%, with an average of 16%. The range of under-reporting for obese subjects was twice as high as in normal-weight subjects, at 25–50%, with an average of 41% (Westerterp and Goris 2002). In a study conducted by Karelis et al., 57.5% of the overweight and obese postmenopausal women were identified as under-reporters (Karelis et al. 2010). In a context of EF measurement, it is also important to note that under-reporting affects not only EI, but also the daily number of eating occasions, and snacks are particularly prone to under-reporting (Bellisle 2004; Livingstone et al. 1990). Table 178.1 presents key features of under-reporting of EI.

To enhance the interpretation of studies examining food and nutrient intake in relation to EF, it is imperative that investigators validate EI data. Considerable caution needs to be employed when interpreting the self-reported energy intakes of weight-conscious subjects.

178.2.2.4 Evaluation of Under-Reporting in Dietary Surveys

There are a number of methods for validating reported EI. The reference methods include: (1) comparison between self-reported EI and the EI required to maintain body weight; (2) comparison between reported nitrogen (equal to protein intake) and 24-h urinary nitrogen excretion; (3) comparison between reported EI and TEE measured by the DLW; (4) comparison between reported EI and presumed energy requirements, both expressed as multiple of basal metabolic rate (BMR) (Goldberg cutoff) (Westerterp and Goris 2002; Livingstone and Black 2003); and (5) comparison of reported EI with predicted TEE using a combination of BMR and physical activity (Livingstone and Black 2003). In EF studies, the DLW technique, the Goldberg cutoff, and the predicted TEE are the most commonly used methods to evaluate dietary under-reporting.

Table 178.1 Key Features of under-reporting of energy intake (Source: Maurer et al. 2006; Livingstone 1995; Karelis et al. 2010; Macdiarmid and Blundell 1997)

1. Under-reporting of EI is a common problem. It can range from 10% to 50% depending on the population and the method and cut-point used to categorize under-reporters.
2. The use of invalid dietary data can biased the understanding of the association between diet and health or body weight.
3. Validity of dietary data can be verified by comparing self-reported EI with measured or estimated TEE.
4. Under-reporting of EI seems to be mainly a consequence of the omission of complete food items or meal/snack. Snacks are particularly prone to under-reporting.
5. Under-reporting of EI has been shown to be more prevalent in women, older adults, people with less education, overweight or obese subjects, and weight-conscious individuals.
6. Dietary patterns of under-reporters of EI include lower carbohydrate intake, lower fat intake, and eating on fewer occasions.
7. Behavioral characteristics of under-reporters of EI include frequent dieting attempts, lower level of physical activity, higher dietary restraint, and higher disinhibition.
8. Psychosocial characteristics of under-reporters of EI include higher social desirability, lower body image, depression, anxiety, and fear of negative evaluation.

This table presents key features of under-reporting food intake including the prevalence of under-reporting, the importance of using valid dietary data, methods to evaluate under-reporting in dietary survey, who under-report their food intake the most, what is most under-reported in general, the dietary patterns of under-reporters, and the psychosocial and behavioral characteristics of food intake under-reporters
EI energy intake, *TEE* total energy expenditure

Doubly Labeled Water

The DLW technique is the gold standard for measuring TEE (Livingstone and Black 2003). The comparison between reported EI and TEE measured by the DLW is also the most accurate method for the validation of reported EI by subjects under free-living situations (Bailey et al. 2007). However, for routine validation of EI data, this method is quite expensive and sophisticated (Bailey et al. 2007; McCrory et al. 2002; Livingstone and Black 2003).

Goldberg Cutoff

An alternative cost-effective technique for identifying inaccurate reports of EI was proposed by Goldberg et al. and Black et al. (Black et al. 1991; Goldberg et al. 1991). This method has been used by numerous investigators to identify under-reporters (Livingstone and Black 2003). In this method, the ratio of reported EI to BMR (EI:BMR) is used as a guide for the accuracy of food records. Reported EI is expressed as a multiple of the BMR estimated from equations and is compared with the presumed mean energy expenditure (EE) of the population, which is also expressed as a multiple of the BMR (EE:BMR). The ratio EE:BMR refers to the physical activity level (PAL). If there is no under-reporting, EE:BMR equals EI:BMR (Goris et al. 2001). A formula was elaborated by Goldberg et al. (1991) to calculate the lower 95% confidence limit of EI:BMR, assuming a given PAL requirement. Values of EI:BMR falling below the 95% confidence limit signify the presence of under-reporting. This formula considers errors associated with the number of subjects (n), the length of the dietary assessment (number of days), variation in both BMR and PAL, and daily variation in EI (Black 2000b).

The Goldberg cutoff has considerable limitations, which have been discussed (Black 2000a). It is best used for identifying the presence of bias in reported EI at the group level, but information on the habitual activity of the population is needed to choose an appropriate PAL for the calculation of appropriate cutoffs. The ability of the Goldberg cutoff to identify under-reporting at the individual level is however limited (Black 2000a). At the individual level, the use of a single cutoff for EI:BMR applied to all subjects is inappropriate. Thus, for identifying under-reporters at the individual level, a short physical-activity questionnaire could be used to assign subjects to suitable PAL levels in large-scale studies. In small studies (n < 100), it would be desirable to obtain a measure of EE using detailed activities diaries, heart-rate monitors, or accelerometers. If these measurements are obtained, a comparison of reported EI and of a more objective measure of EE can be made, consequently reducing the limitations associated with the EI:BMR cutoff.

Predicted Total Energy Expenditure: Combination of Basal Metabolic Rate and Physical Activity Energy Expenditure

An easy and inexpensive method for validating reported EI of individuals is a combination of BMR (measured or calculated) and physical activity energy expenditure (PAEE), which can be assessed by physical-activity diaries, questionnaires, heart-rate monitors, or accelerometers. Accelerometers seem to be the most objective method that can be used to quantify PAEE at individual level in free-living situations (Goris et al. 2001). It was shown that the combination of measured resting metabolic rate (RMR) with PAEE was able to explain 85% of the variation in TEE measured with DLW (Westerterp and Goris 2002). Goris et al. (2001) found no significant difference between the percentages of under-reporting assessed with a tri-axial accelerometer as compared with DLW. The use of a combination of BMR (measured) and PAEE seems to be a good method for validating reported EI.

178.3 Part II: Eating Frequency and Body-Weight Status

Does snacking make you fat? There is a belief that eating between meals (snacking) leads to weight gain. Public-health advice for body weight control often suggests to avoid snacking between meals in order to not increase total EI (Kirk 2000). It has been suggested that snacking may be a cause of obesity, if, as assumed, the consumption of snack foods between meals increases total EI (Booth 1988; Basdevant et al. 1993). The work of Booth (1988) is frequently cited as evidence that snacking leads to over-consumption. Results reported by Booth suggest that snacks and/or high-energy drinks taken more than 1 h before meals fail to exert satiety and energy compensation (i.e., energy consumed at main meals is reduced) at subsequent meals, leading to overeating and ultimately to obesity. However, evidence supporting the implication of frequent eating in obesity is not that clear (Bellisle et al. 1997; Palmer et al. 2009).

178.3.1 Adult Studies

Many epidemiological and clinical studies have explored the association between EF and body weight in adults, but results have been inconsistent. Some studies observed an inverse relation between EF and body weight (Fabry et al. 1964; Metzner et al. 1977; Charzewska et al. 1981; Kant et al. 1995; Burley et al. 2002; Ruidavets et al. 2002; Drummond et al. 1998; Ma et al. 2003; Chapelot et al. 2006; Duval et al. 2008a), whereas others failed to detect any significant association (Dreon et al. 1988; Edelstein et al. 1992; Summerbell et al. 1996; Yannakoulia et al. 2007; Andersson and Rossner 1996) (see Table 178.2). One study observed a positive relationship between EF and

Table 178.2 Summary of studies investigating the relationship between eating frequency and adiposity in adults

Reference	Study population	EF measure: Method	EF measure: Definition	EF measure: EF (daily)	Control for under-reporting	Adiposity measures	Statistical significance
Fabry et al. (1964)	379 M; 60–64 years	Interview with a trained dietician	Data not provided	≤3, 3–4, ≥5	No	Overweight TSF SSF	Significant negative correlations[a]
Metzner et al. (1977)	2,028 M + F; 35–69 years	24-h diet recall interview	Time interval between two eating occasions	1 to ≥8	No	Adiposity index[b]	Significant negative correlations[a]
Charzewska et al. (1981)	886 M; 40–59 years	Data not provided	Data not provided	2, 3–4, 5–7	No	%BF[c] BMI	Significant negative correlations[a]
Dreon et al. (1988)	155 M; 30–59 years	7-day food diary	Predefined eating periods	1–7	No	%BF[c] BMI	$r = -0.07$, NS $r = -0.03$, NS
Edelstein et al. (1992)	2,034 M + F; 50–89 years	Diet-assessment questionnaire	Data not provided	1–2, 3, ≥4	No	BMI Waist: hip	NS[a] Significant negative correlation[a]
Kant et al. (1995)	7,147 M + F; 25–74 years (Baseline)	24-h dietary recall	Time interval between two eating occasions	≤2 to ≥7	No	Weight change Baseline BMI TSF[d] SSF	Significant negative correlations[a]
	7,101 M + F; 35–84 years (Follow-up)	Two questions on snack and meal frequency	Time interval between two eating occasions	≤2 to ≥7	No	Weight change Baseline BMI TSF[e] SSF[e]	NS[a] NS[a] NS[a] NS[a]
Summerbell et al. (1996)	220 M + F; *Elderly* (65–91 years) *Working age* (17–60 years) *Middle-aged* (39–59 years) *Adolescent* (13–14 years)	7-day weighed food record	Predefined eating periods	1–3, 4–6	Yes	*Elderly*: BMI *Working age*: BMI *Middle-aged*: BMI *Adolescents*: BMI	 NS[a] NS[a] NS[a] NS[a]

Andersson et al. (1996)	147 M; 20–60 years	24-h dietary recall	Predefined eating periods	3.8–9.5	Yes	BMI	NS[a]
Drummond et al. (1998)	95 M + F; 20–55 years	7-day food diary	Time interval between two eating occasions	2.4–9.0	Yes	*Men*:	
						Body weight	$r = -0.34$, S
						BMI	$r = -0.26$, NS
						%BF[f]	$r = -0.21$, NS
						Women:	
						Body weight	$r = -0.14$, NS
						BMI	$r = -0.15$, NS
						%BF[f]	$r = -0.01$, NS
Ruidavets et al. (2002)	330 M; 45–64 years	3-day food diary	Time interval between two eating occasions	1–2, 3, 4, >5	Yes	BMI Waist: hip	Significant negative correlations[a]
Burley et al. (2002)	1,214 F; 35–69 years	4-day food diary	Time interval between two eating occasions	Low 5.6, Medium 7.7 High 10.4	No	Body weight[g] BMI HC[g]	Significant negative correlations[a]
						WC[g]	NS[a]
						Waist: hip	NS[a]
Ma et al. (2003)	499 M + F; 20–70 years	24-h dietary recall	Time interval between two eating occasions	≤3, ≥4	No	Obesity	Significant negative correlation[a]
Chapelot et al. (2006)	24 M; 19–25 years	3 weekdays' food diary	Data not provided	3–4 or 4–3	No	Body weight	NS[a]
						BMI	NS[a]
						FM[h]	Significant negative correlation[a,i]
Howartz et al. (2007)	2,685 M + F; *Younger* (20–59 years) *Older* (60–90 years)	24-h dietary recalls	Time interval between two eating occasions	≤3, 3.5–6, >6	Yes	BMI	Significant positive correlation[a]

(continued)

Table 178.2 (continued)

Reference	Study population	EF measure: Method	EF measure: Definition	EF (daily)	Control for under-reporting	Adiposity measures	Statistical significance
Yannakoulia et al. (2007)	220 F; 24–74 years	3-day food diary	Time interval between two eating occasions	2.7–10.0	Yes	*Premenopausal women*:	
						BMI	$r = 0.16$, NS
						%BF[h]	$r = 0.17$, NS
						WC	$r = 0.11$, NS
						Waist: hip	$r = 0.15$, NS
						Postmenopausal women:	
						BMI	$r = 0.16$, NS
						%BF[h]	$r = 0.30$, S
						WC	$r = 0.08$, NS
						Waist: hip	$r = -0.16$,NS
Duval et al. (2008a)	85 F; 47–56 years	7-day food diary	Time interval between two eating occasions	3.0–7.1	Yes	Body weight	$r = -0.19$, NS
						BMI	$r = -0.25$, S[j]
						WC	$r = -0.32$, S
						%BF[h]	$r = -0.26$, S[j]
						FM[h]	$r = -0.27$, S[j]
						FFM[h]	$r = -0.04$, NS

This table presents a summary of studies that have investigated the relationship between EF and adiposity in adults. It gives some information about the study population, methods used to assess EF, definition choose to describe EF, categories of EF used to compare the results, information about the control of under-reporting, adiposity measures used to assess the relationship between EF and adiposity, and statistical significance of the results

EF eating frequency, *TSF* triceps skinfold, *SSF* subscapular skinfold, *BMI* body mass index, *WC* waist circumference, *%BF* percentage of body fat, *FM* fat mass, *FFM* fat-free mass, *NS* Not significant, *S* significant, *M* male, *F* female

[a]The correlation coefficients are not provided

[b]Adiposity index combines two skinfold measurements, height, and weight

[c]Measured from underwater weighing

[d]Significant negative correlation for women only

[e]Significant negative correlation for men only

[f]Estimated using the method of Durnin and Womersley

[g]Self-reported measures

[h]Measured from dual-energy X-ray absorptiometry

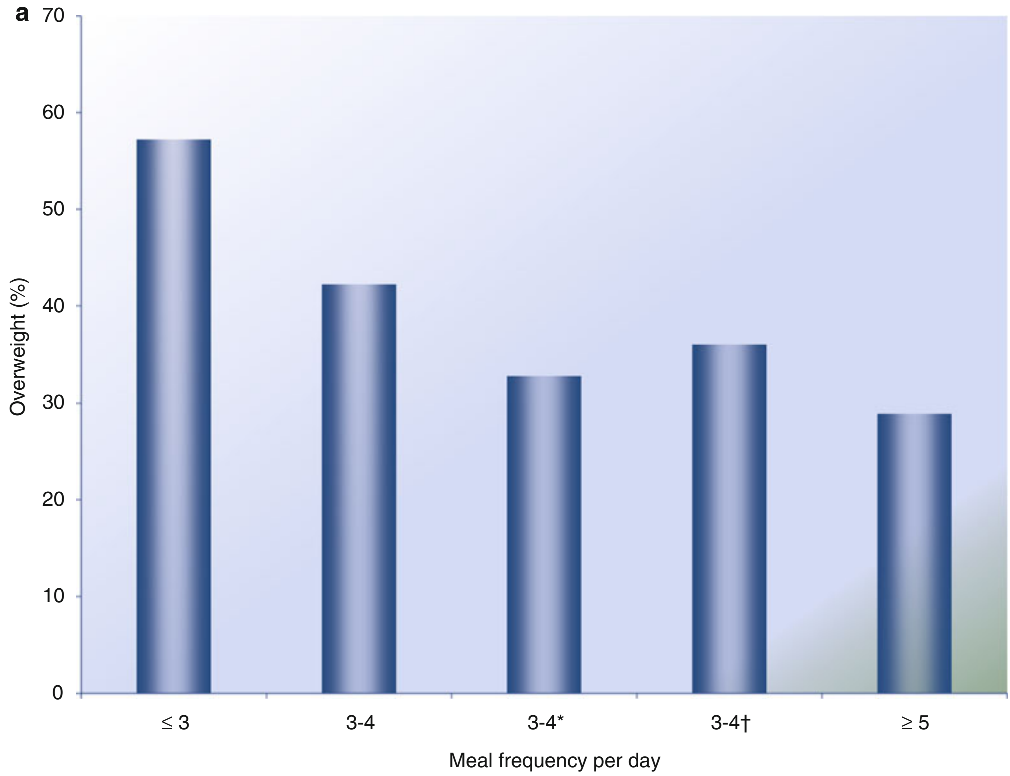
[i]Significant only for the group who switch from a four- to a three-meal pattern by removing their usual afternoon meal

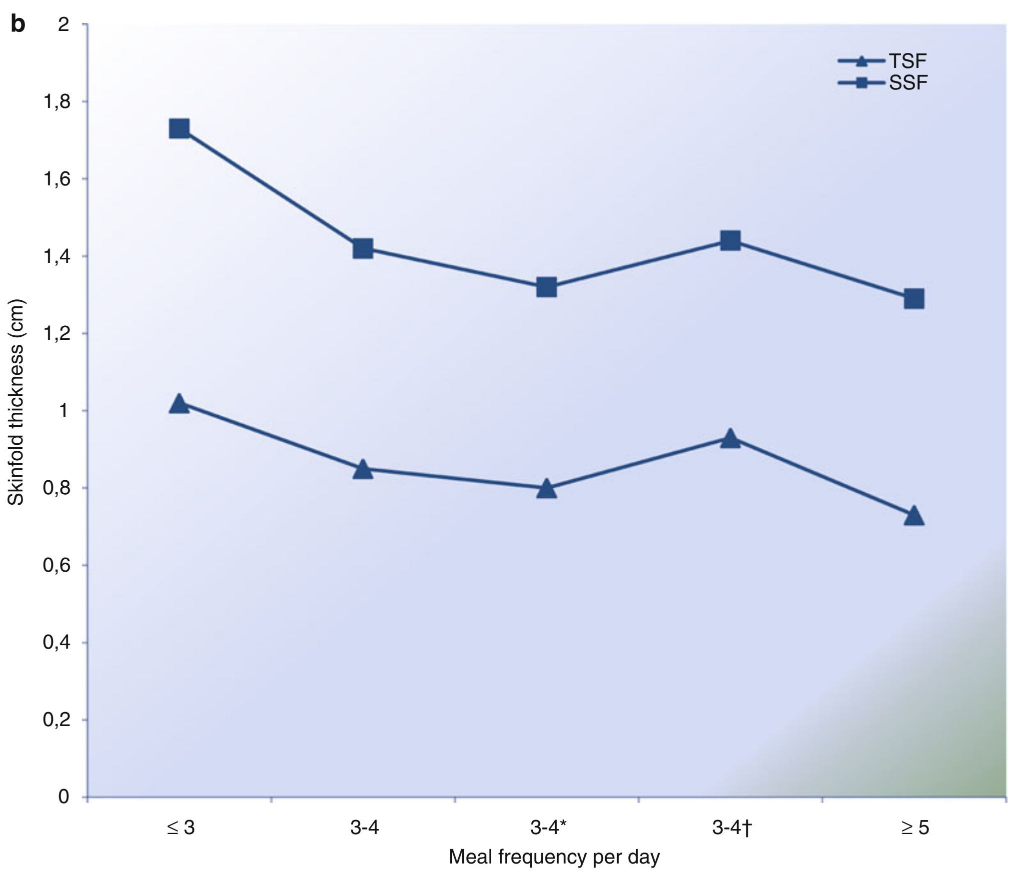
[j]The associations between adiposity and EF disappeared after correction for PAEE and VO_{2peak}

obesity (Howarth et al. 2007). Howarth et al. (2007) observed that eating more than three times a day was associated with being overweight or obese in both younger (20–59 years) and older (60–90 years) groups. Fabry et al. (1964) were the first investigators to show an inverse association between EF and body weight, suggesting that a “nibbling” pattern could help to prevent obesity. They found that, in a sample of 379 men aged 60–64 years, skinfold thickness and incidence of overweight were significantly greater in those who consumed three or less meals a day compared to those who ate five or more meals a day (see Fig. 178.3 a, b). Metzner et al. (1977) also studied the relationship between EF and adiposity in 2,028 men and women aged 35–69 years. They found that subjects who ate six meals a day had a significantly lower adiposity index than those who ate two meals a day. In a cross-sectional study, EF and body mass index (BMI) were assessed in 220 free-living people in four age groups (adolescent, working age, middle-aged, and elderly) (Summerbell et al. 1996). Summerbell et al. (1996) found no significant relationship between eating pattern and BMI for each group after exclusion of under-reporters (see Fig. 178.4). More recently, Drummond et al. (1998) showed that eating more frequently was related to leanness in men but not in women. In women, although a positive correlation between EF and EI was observed, no relation was found between body weight and EF. A positive association between EF and PAEE at leisure time was found in women, suggesting that the higher EI associated with a high EF appears to have been balanced by greater EE from physical activity, sufficient to prevent an increase in body weight. Yannakoulia et al. (2007) found similar results in a cross-sectional study of 220 women. Indeed, they demonstrated that, in premenopausal women, frequent eating was not related to adiposity, but it was associated with high EI and high EE, especially PAEE spent at home. They also observed that EF was positively correlated with adiposity and EI in postmenopausal women. Possible explanations could be that frequent eating is not associated with a physically active lifestyle in postmenopausal women. In middle-aged women, decrease in RMR and physical activity could be accentuated (Evenson et al. 2002). This decline in EE, without a proportional reduction in EI, may explain a higher adiposity level in postmenopausal women who also display frequent eating patterns. Another study reinforces the findings of Drummond et al. (1998) and Yannakoulia et al. (2007). In a sample of 85 premenopausal women, Duval et al. (2008a) found that women who ate more frequently tended to have higher EI, but they were also leaner (see Fig. 178.5). Interestingly, they noted that the association between adiposity and EF disappeared after correction for PAEE and VO_{2peak}. These results indicated that a physically active lifestyle may be an important confounder of the relationship between adiposity and eating frequency. In a cross-sectional study where EF was collected at five equally spaced time points over a 1-year period in 499 participants, Ma et al. (2003) found that subjects who reported four or more eating episodes per day had a lower obesity risk, which is decreased by 45%.

178.3.2 Children Studies

Similar to results in adults, in children and adolescents, the association between EF and body weight is also inconclusive (see Table 178.3). Fabry et al. were again among the first investigators to show an inverse association between EF and body weight in children (Fabry et al. 1966). They performed a 1-year intervention study in which 226 children aged 6–16 years in three schools were selected for comparison. Children in one school were allowed to continue their habitual eating pattern of five meals a day. Children in the second school were switched to three meals a day and children in the third school to seven meals daily. After 1 year, the children who ate seven meals a day were charac-


a
70
60
50
40
30
20
10
0
Overweight (%)
≤ 3
3-4
3-4*
3-4†
≥ 5
Meal frequency per day


b
2
1,8
1,6
1,4
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1
0,8
0,6
0,4
0,2
0
Skinfold thickness (cm)
TSF
SSF
≤ 3
3-4
3-4*
3-4†
≥ 5
Meal frequency per day

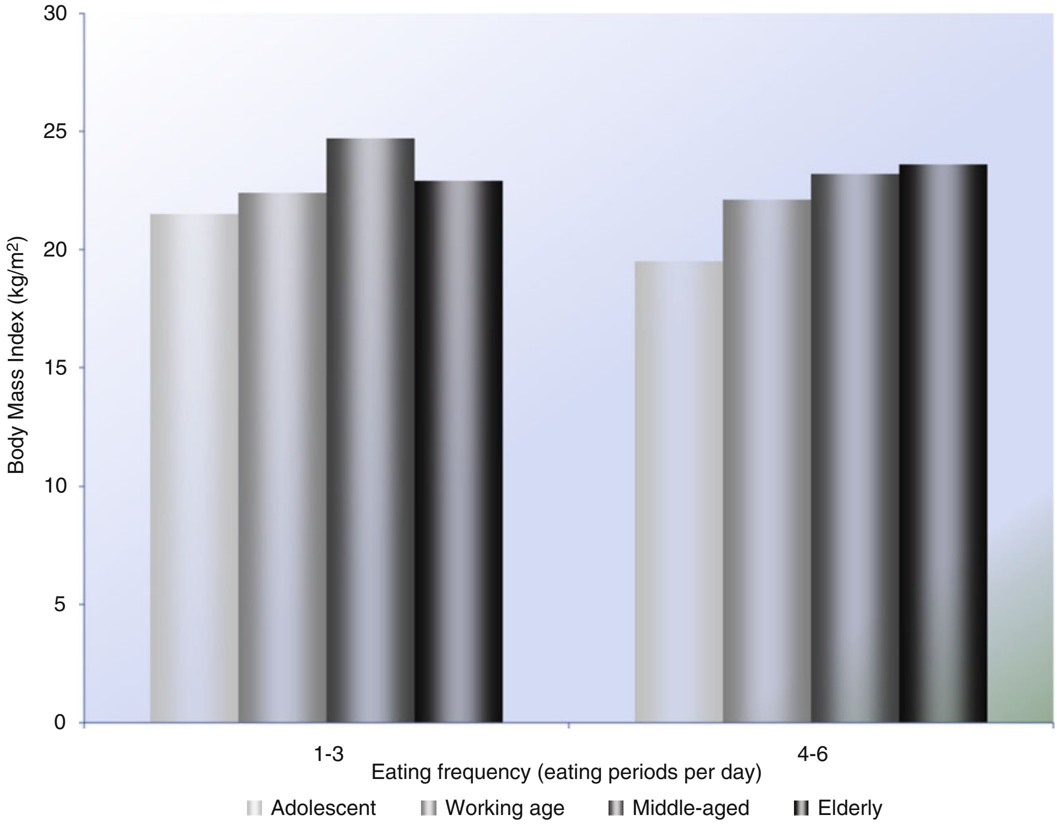

Fig. 178.4 Relationship between eating frequency and body mass index in 220 free-living people in four age groups. This figure shows that there was no relationship between BMI and EF for the four age groups after exclusion of invalid food records. Results presented are means, *n* = adolescent (33); working age (59); middle-aged (40); and elderly (88) (Data from Summerbell et al. 1996)

terized by significantly lower body weight and skinfold thickness. In another study conducted by Toschke et al., the prevalence of overweight and obesity decreased along with the number of meals per day in a sample of 4,370 German children aged 5–6 years (Toschke et al. 2005). The prevalence of obesity in children who ate three or fewer meals was 4.2%; four meals, 2.8%; and five or more meals, 1.7%. In this cohort, a higher EF was inversely related to the prevalence of childhood overweight and obesity, suggesting that a frequent eating pattern might exert protective effects against excess adiposity. In a large sample of schoolchildren aged 6–11 years participating in a cross-sectional survey of childhood obesity, Barba et al. (2006) found that daily EF was inversely associated with adiposity and central fat deposition (see Fig. 178.6 a, b). Also, in a 10-year longitudinal study, Franko et al. also found that girls who ate more than three meals per day had lower BMI *z*-scores for

Fig. 178.3 (**a**) Relationship between meal frequency and incidence of overweight in 379 men aged 60–64 years. This figure shows that the incidence of overweight tended to increase as the frequency of meals decreases in men aged 60–64 years. *Additional snacks between meals; †Additional snack at bedtime. Results presented are means (Data from Fabry et al. 1964) (**b**) Relationship between meal frequency and adiposity in 379 men aged 60–64 years. This figure shows that adiposity, measured by skinfold thickness, tended to decrease as the frequency of meals increases in men aged 60–64 years. TSF: Triceps skinfold thickness; SSF: Subscapular skinfold thickness; *Additional snacks between meals; †Additional snack at bedtime. Results presented are means (Data from Fabry et al. 1964)

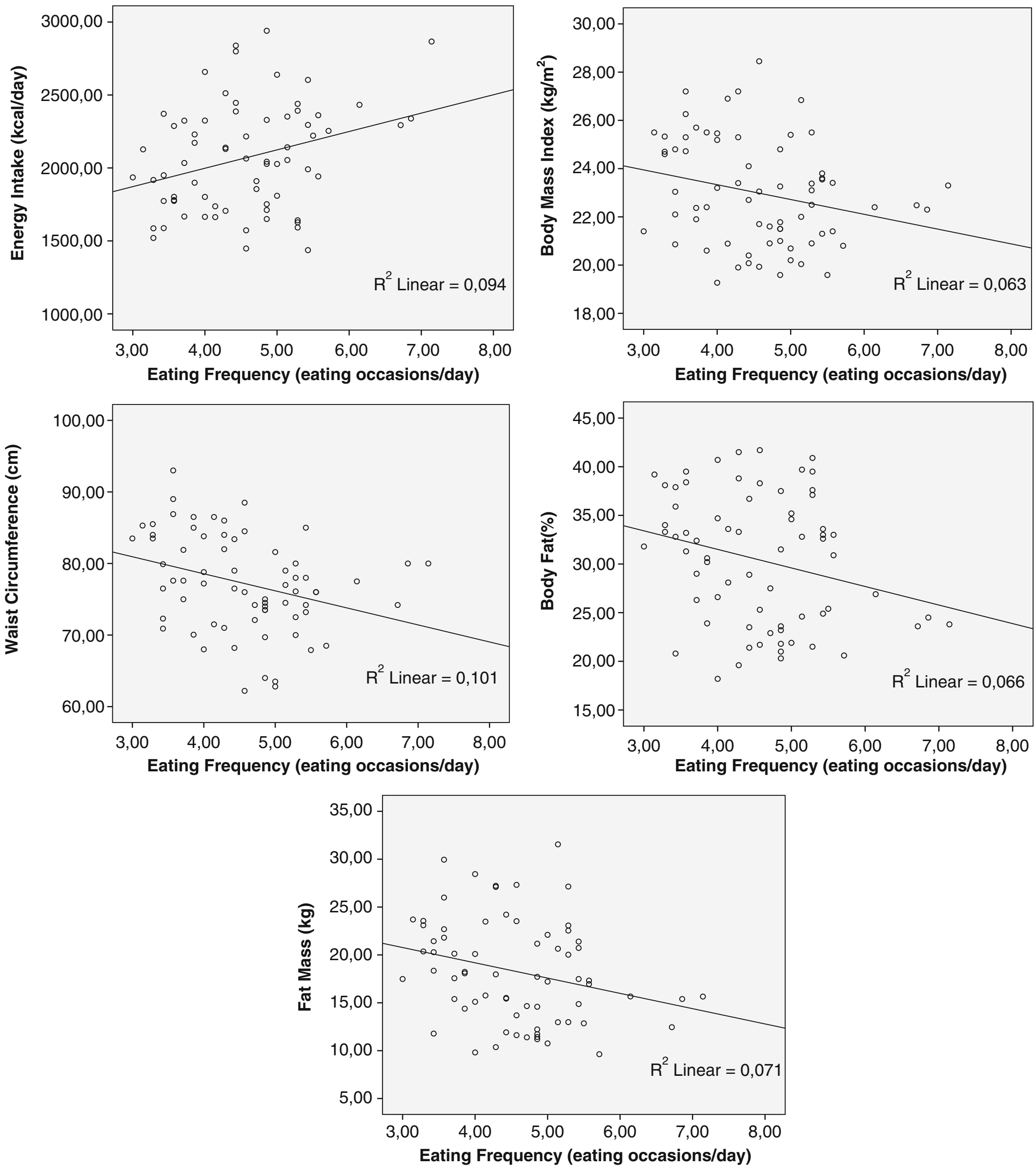

Fig. 178.5 Effects of eating frequency on energy intake and body composition in 85 premenopausal women. This figure illustrates correlations of EF with EI and body composition in a sample of 85 premenopausal women. These correlations show that EF was positively associated with EI and negatively associated with adiposity, measured by dual-energy X-ray absorptiometry. Women who ate more frequently tended to have higher EI, but they had also lower adiposity. However, these associations disappeared after correction for PAEE and VO_{2peak}. Values were obtained with the use of Pearson's correlation coefficient (Data from Duval et al. 2008a)

age (Franko et al. 2008). Zerva et al. conducted a study in a sample of 151 children aged 9–11 years (Zerva et al. 2007). Children were categorized in tertiles based on the daily number of eating occasions (≤4.1, 4.2–5.4, and ≥5.5). Physical activity was also assessed with 4-day accelerometry. The results of this study have shown that a higher EF was associated with a better body composition. This association occurred despite the higher EI of the frequent eaters compared with the non-frequent

Table 178.3 Summary of studies investigating the relationship between eating frequency and adiposity in children

Reference	Study population	EF measure: Method	EF measure: Definition	EF measure: EF (daily)	Control for under-reporting	Adiposity measures	Statistical significance
Fabry et al. (1966)	226 M + F; 6–16 years	Dietician	Data not provided	3, 5, and 7	No	Body weight SFT	Significant negative correlations[a]
Morgan et al. (1983)	972 M + F; 5–18 years	7-day food diary	Predefined eating periods	1–5	No	BMI[b]	NS[a]
Ruxton et al. (1996)	136 M + F; 7–8 years	7-day weighed food record	Predefined eating periods	Low and high snackers	No	Body weight BMI SFT	NS[a] NS[a] NS[a]
Crawley and Summerbell (1997)	731 M + F; 16–17 years	4-day food diary	Time interval between two eating occasions	Data not provided	Yes	BMI	NS[a]
Nicklas et al. (2003)	1,562 M + F; 10 years	24-h dietary recall	Time interval between two eating occasions	Data not provided	No	Overweight status	NS[a]
Nicklas et al. (2004)	1,584 M + F; 10 years	24-h dietary recall	Time interval between two eating occasions	2–11	No	Overweight status	NS[a]
Toschke et al. (2005)	4,370 M + F; 5–6 years	Self-administered questionnaire	Predefined eating periods	≤3, 4 and ≥5	Yes	Overweight Obesity	Significant negative correlations[a]
Barba et al. (2006)	3,668 M + F; 6–11 years	"Yes" or "No" questions referring to the EF of the last 12 months	Predefined eating periods	≤3, 4, and ≥5	No	BMI WC	Significant negative correlations[a]
Zerva et al. (2007)	131 M + F; 9–11 years	3-day food diary	Time interval between two eating occasions	≤4.1, 4.2–5.4, and ≥5.5	Yes	SFT %BF[c] TER[d]	$r = -0.17$, S $r = -0.18$, S Significant negative correlation[a]
Franko et al. (2008)	2,375 F; 9–19 years	3-day food diary	Time interval between two eating occasions	≤3 and >3	No	BMI	Significant negative correlation[a]

This table presents a summary of studies that have investigated the relationship between EF and adiposity in children. This table gives some information about the study population, methods used to assess EF, definition choose to describe EF, categories of EF used to compare the results, information about the control of under-reporting, adiposity measures used to assess the relationship between EF and adiposity, and statistical significance of the results

EF eating frequency, *SFT* skinfold thickness, *BMI* body mass index, *WC* waist circumference, *%BF* percentage of body fat, *TER* trunk-to-extremity ratio, *NS* not significant, *S* significant, *M* male, *F* female

[a]The correlation coefficients are not provided

[b]Self-reported measures

[c]Percent of body fat was estimated from triceps and subscapular skinfolds from which fat mass and fat-free mass were calculated

[d]The trunk-to-extremity ratio (TER) is an index of body-fat distribution. It was calculated by dividing the sum of central (subscapular and suprailiac) by the sum of peripheral skinfolds (triceps and biceps)

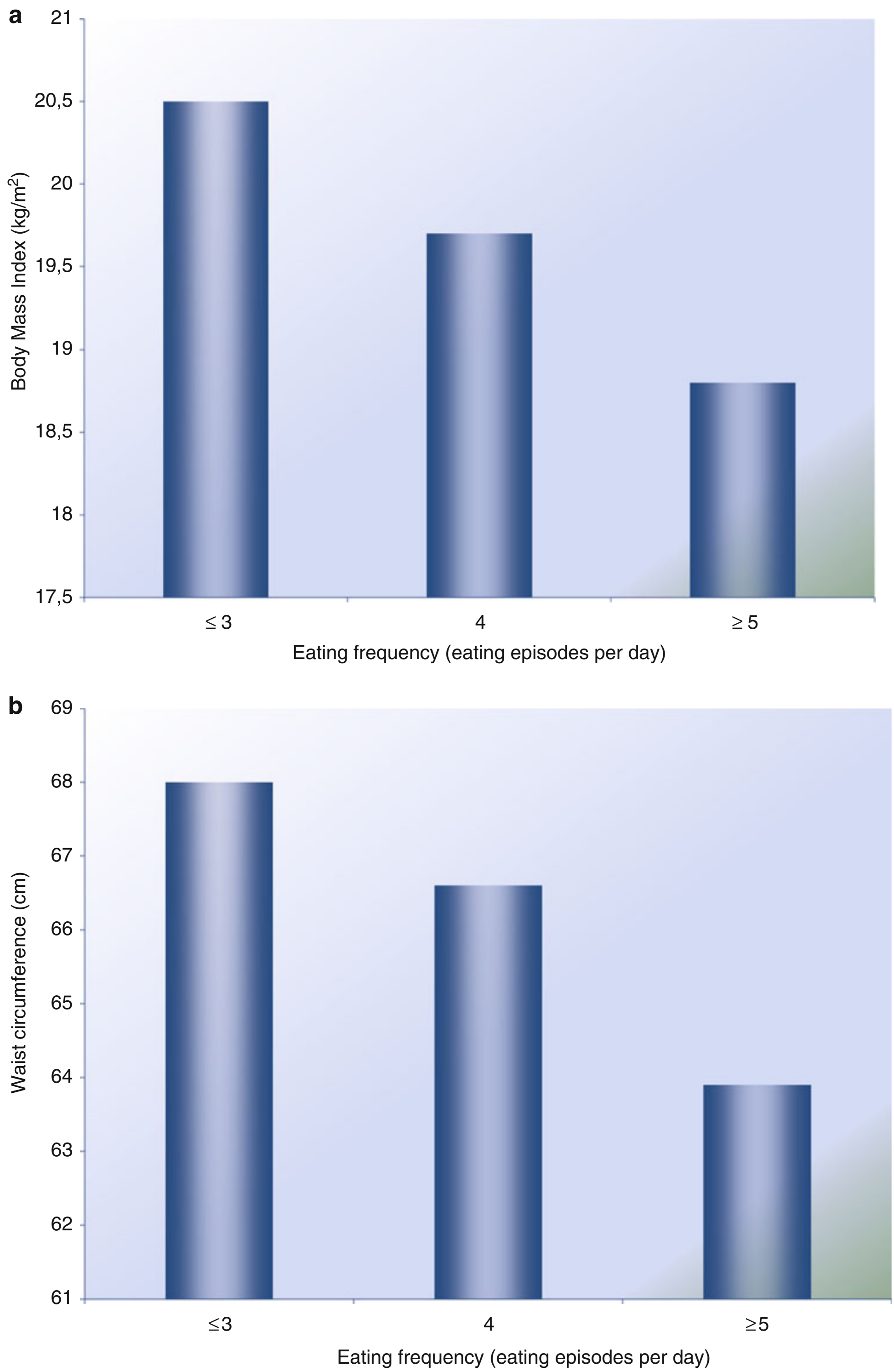

Fig. 178.6 (**a**) Relationship between eating frequency and body mass index in 3,668 school-children aged 6–11 years in the ARCA project. This figure shows that BMI was negatively associated with EF in schoolchildren aged 6–11 years. Results presented are means, $n = \leq 3$ (332); 4 (1334); and ≥5 (2002) (Data from Barba et al. 2006) (**b**) Relationship between eating frequency and waist circumference in 3,668 schoolchildren aged 6–11 years in the ARCA project. This figure shows that waist circumference was negatively associated with EF in schoolchildren aged 6–11 years. Results presented are means, $n = \leq 3$ (332); 4 (1334); and ≥5 (2002) (Data from Barba et al. 2006)

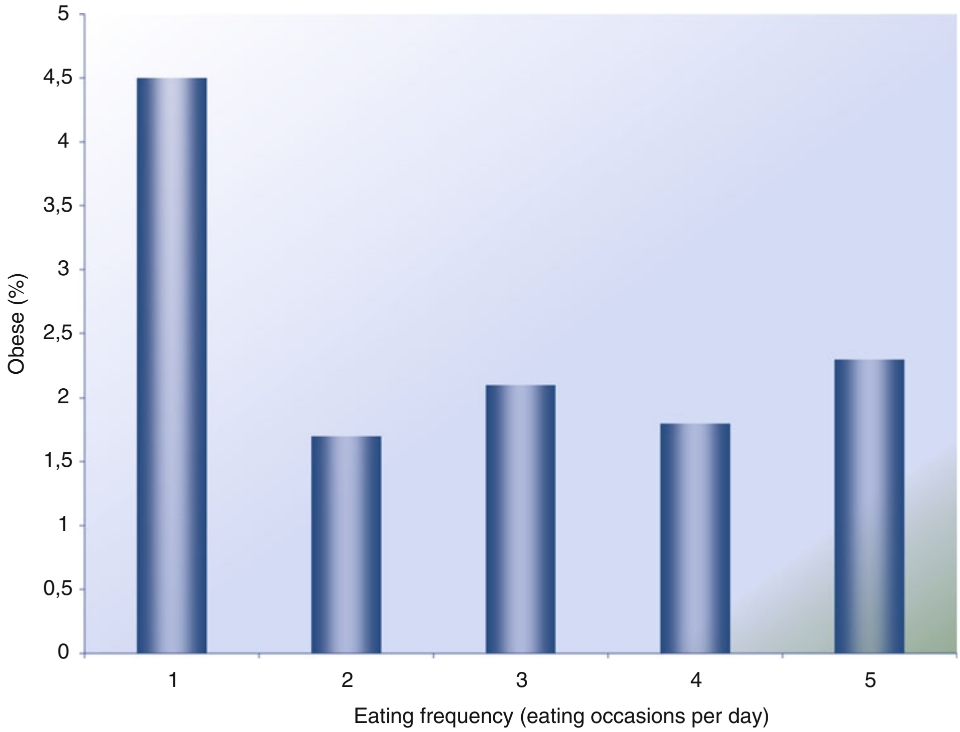

Fig. 178.7 Relationship between eating frequency and obesity in 972 children aged 5–18 years. This figure shows that there was no significant relationship between EF and occurrence of obesity in children aged 5–18 years. Results presented are means, n = 1 (267); 2 (129); 3 (129); 4 (162); and 5 (281) (Data from Morgan et al. 1983)

eaters. Higher physical activity was found in the frequent-eaters group, and it was suggested that this result may, at least partially, explain the findings of this study.

By contrast, findings from others' studies in children failed to identify a significant association between EF and childhood obesity (Morgan et al. 1983; Ruxton et al. 1996; Nicklas et al. 2003, 2004; Crawley and Summerbell 1997). In a group of schoolchildren, Ruxton et al. (1996) found no significant association between snacking frequency and weight, BMI, or skinfold thickness. These results confirm the findings of Morgan et al. (1983) reported 10 years earlier in a group of children aged 5–18 years. In this study, no relationship between eating patterns and obesity was observed (see Fig. 178.7). As well, they found no differences in snacking frequency between obese, heavy, average, and normal weight children. Similarly, results from Crawley et al. (1997) failed to produce results supporting a significant association between BMI and EF in a free-living sample of teenagers aged 16–17 years. Finally, in two different studies based on data from the Bogalusa Heart Study, Nicklas et al. (2003, 2004) found no significant relationship between overweight status and the number of eating episodes.

178.3.3 Weight-Loss Studies

The potential benefits of a nibbling versus a gorging meal pattern for body-weight loss were investigated in obese patients. With the exception of only one study, there is no evidence that EF can have a significant impact on weight loss in energy-restricted diets (see Table 178.4) (Bellisle et al. 1997;

Palmer et al. 2009). Indeed, most of the interventional studies failed to show any influence of EF on weight loss (Bortz et al. 1966; Young et al. 1971; Garrow et al. 1981; Finkelstein and Fryer 1971; Antoine et al. 1984; Schlundt et al. 1992; Verboeket-van de Venne and Westerterp 1993; Poston et al. 2005; Vander Wal et al. 2006; Berteus Forslund et al. 2008; Cyr et al. 2007; Duval et al. 2008b). In 1973, Debry et al. have shown a greater weight loss in dieting overweight subjects who were eating seven meals a day than in those who were eating only three meals a day (142 vs 78 g/day) (Debry et al. 1973). However, as shown in Table 178.4, other studies which have addressed the same issue found no significant effect of EF on weight loss. In a crossover study, Bortz et al. (1966) saw no difference in weight loss in a group of six obese women on an isoenergetic diet of 600 kcal daily in either one, three, or nine meals per day. Finkelstein and Fryer (1971) and Young et al. (1971) conducted weight-loss studies in students. The effects of different meal patterns (one, three, or six meals/day – Young et al.; three or six meals/day – Finkelstein and Fryer) were studied. Both studies failed to show any significant relationship between meal frequency and weight change. In a study conducted by Garrow et al. (1981), obese subjects were on an 800 kcal/d diet over 3 weeks. Weight loss was lower when subjects ate five times per day (0.22 kg/day) compared with one meal per day (0.26 kg/day), but this difference was not statistically significant. Verboeket-van de Venne et al. (1993) found that the intake of two or three to five meals per day has no significant effect on the rate and composition of weight loss in obese women on a 1,000 kcal/day diet. More recently, Duval et al. (2008b) found that eating more frequently does not seem to be related with a better body-weight status during weight loss in a sample of 79 obese postmenopausal women who participated in a 6-month weight-reduction program consisting of an 500–800 kcal daily energy deficit. In an 8-week study where subjects were prescribed a dietary energy restriction of 700 kcal/day, Cyr et al. (2007) shown that eating six versus three times per day does not promote greater weight loss. Also, in a ten-y prospective study, Burley et al. found that more-frequent eating and drinking was not associated with greater weight gain in middle-aged women (Burley et al. 2008). Finally, Berteus et al. (2008) observed that recommending snacks or not between meals does not influence 1-year weight loss. In summary, weight loss is not facilitated by high EF.

178.3.4 How Could High Eating Frequency Help Weight Management?

Kirk (2000) highlighted some of the possible advantages associated with a high EF that may help in the control of body weight. First, several studies have shown that snack foods are often higher in carbohydrates and lower in fat than meals (Basdevant et al. 1993; Summerbell et al. 1995; Drummond et al. 1996; Kirk 2000). Thus, a higher EF may be associated with an increased carbohydrate: fat ratio, which may be beneficial in body-weight control. Studies show that high-fat diets are positively associated with overweight and obesity, whereas high-carbohydrate diets are associated with leanness (Gazzaniga and Burns 1993; Miller et al. 1990; Tucker and Kano 1992). Second, eating more frequently may help to spread the EI over the day. It was suggested that obese individuals tend to eat little in the morning (skip breakfast) and much in the afternoon and the evening (Bellisle 2004; Fricker et al. 1990). Furthermore, it was shown that an individual who consumed fewer meals per day and who consumes more food in the evening may be more prone to weight gain (Fricker et al. 1990). Third, another argument for the potential beneficial effects of frequent eating on body-weight control relates to the reduction in hunger that has been postulated to occur with higher EF (Drummond et al. 1996). Burley et al. have shown that eating five times per day (three meals and two snacks) rather than three meals resulted in a flatter profile of hunger throughout the day (Burley et al. 1993). Eating more frequently may also have a beneficial effect in preventing subsequent overcompensation (Westerterp-Plantenga et al. 1994). In addition, spreading the energy load over the day by including

Table 178.4 Summary of weight-loss studies comparing different eating frequency patterns

Reference	Study population	Weight-loss duration	EF pattern	Weight and adiposity changes	Statistical significance
Bortz et al. (1966)	6 F;	60 days	3	No data provided	NS[a]
	19–56 years;	(20 days on each	1	−0.23 kg/day	
	Obese	EF pattern)	9	−0.24 kg/day	
Finkelstein and Fryer (1971)	8 F[b];	60 days	3	−6.1 kg	NS[a]
	20–22 years;		6	−5.5 kg	
	BMI 27–33 kg/m²				
Young et al. (1971)	11 M;	5 weeks' crossover	1	−6.08 ± 1.03 kg	NS[a]
	20–25 years;	(14 weeks in total)	3	−4.88 ± 1.31 kg	
	Mean BMI 34 kg/m²		6	−6.10 ± 1.75 kg	
				Greater versus lesser EF	
				−0.12 ± 0.84 kg FM[c]	NS[a]
Debry et al. (1973)	32 M + F;	1-month crossover	3 and 7	−78 g/day	Significant positive correlation[a]
	16–65 years;				N > G
	120–220% IBW				
Garrow et al. (1981)	14 F;	3 weeks[d]	1	−0.26 kg/day	NS[a]
	18–56 years;		5	−0.22 kg/day	
	Mean BMI 37.7 kg/m²				
Antoine et al. (1984)	10 F;	2 weeks' crossover	3	−0.15 ± 0.05 kg/day	NS[a]
	Mean age 41 years;		6	−0.18 ± 0.05 kg/day	
	Mean BMI 31.8 kg/m²				
Schlundt et al. (1992)	52 F;	12 weeks	2 meals (breakfast eater who now has no breakfast)	−8.9 ± 4.2 kg	NS[a]
	18–55 years;				
	Mean BMI 30.6 kg/m²		2 meals (breakfast skipper who now has no breakfast)	−6.0 ± 3.9 kg	
			3 meals (breakfast eater who now has no breakfast)	−6.2 ± 3.3 kg	
			3 meals (breakfast skipper who now eats breakfast)	−7.7 ± 3.3 kg	
Verboeket-van de Venne and Westerterp (1993)	14 F;	4 weeks[e]	2	−4.1 ± 0.5 kg BW	NS[a] for BW, FM and FFM
	20–58 years;			−2.3 ± 0.6 kg FM	
	Mean BMI 30.2 kg/m²		3–5	−1.8 ± 0.5 kg FFM	
				−4.7 ± 0.4 kg BW	
				−2.7 ± 0.5 kg FM	
				−2.0 ± 0.4 kg FFM	

(continued)

Table 178.4 (continued)

Reference	Study population	Weight-loss duration	EF pattern	Weight and adiposity changes	Statistical significance
Poston et al. (2005)	100 M + F; 40–42 years; BMI 31–33 kg/m²	24 weeks	3 meals (snacker) 3 meals + 3 snacks (non-snacker) 3 meals + 3 snacks (snacker) 3 meals (non-snacker)	−2.9 ± 3.2 kg −3.5 ± 5.5 kg −2.4 ± 3.2 kg −2.1 ± 3.4 kg	NS[a]
Vander Wal et al. (2006)	80 M + F; 45–48 years; Mean BMI 38 kg/m²	8 weeks	3 meals + 2 snacks (post-dinner snack) 3 meals + 1 snack (no post-dinner snack)	−3.7 ± 3.3 kg BW −5.6 ± 6.0 kg WC −1.5 ± 1.7 kg %BF −4.7 ± 3.8 kg BW −7.3 ± 5.9 kg WC −1.3 ± 2.6 kg %BF	NS[a] for BW, WC and %BF
Berteus Forslund et al. (2008)	140 M + F; Mean age 39–40 years; Mean BMI 38 kg/m²	52 weeks	3 6 (3 meals + 3 snacks)	−4.1 ± 6.1 kg −5.9 ± 9.4 kg	NS[a]
Cyr et al. (2007)	16 M + F; Mean age 35 years; Mean BMI 37.1 kg/m²	8 weeks	3 6 (3 meals + 3 snacks)	−4.7% BW −3.1 ± 2.9 kg FM −2.0 ± 3.1 kg FFM −1.7 ± 0.8 kg/m² BMI	NS[a] NS[a] NS[a] NS[a]
Duval et al. (2008b)	79 F; 50–69 years; Mean BMI 32.6 kg/m²	6 months	No specific EF pattern	−6.9% BW	NS[a,f]

This table presents a summary of weight-loss studies that have compared the effect of different EF patterns on weight loss. This table gives some information about the study population, weight-loss duration, EF patterns used to compare the results, weight and adiposity changes, and statistical significance of the results (Adapted from Bellisle et al. 1997)

EF eating frequency, *IBW* ideal body weight, *FM* fat mass, *FFM* fat-free mass, *BW* body weight, *BMI* body mass index, *%BF* percentage of body fat, *WC* waist circumference, *N* nibbling, *G* gorging, *NS* not significant, *M* male, *F* female

[a]The correlation coefficients are not provided

[b]Four subjects followed each EF pattern

[c]Measured from underwater weighing

[d]Participants were on a three-meal EF regimen for the first week. Eating-frequency effect was tested for 1 week during weeks 2 and 3 in randomized order

[e]Seven subjects followed each EF pattern

[f]Analyses were repeated controlling for PAEE with no change in the results

Table 178.5 Summary of studies that have investigated the effect of eating frequency on total energy expenditure

Reference	Study population	Measure	EF pattern	TEE	Statistical significance
Dallosso et al. (1982)	8 M; 18–23 years; Mean BMI 22 kg/m²	24-h EE 7–14 days' adaptation	2 6	9,759 ± 408 kJ/day 9,639 ± 314 kJ/day	NS[a]
Wolfram et al. (1987)	8 M + F; 20–23 years; Mean BMI 23 kg/m²	48-h EE 14 days' adaptation	1 5	8.42 ± 1.15 MJ/day 8.37 ± 1.32 MJ/day	NS[a]
Verboeket-van de Venne and Westerterp (1991)	13 M + F; 18–23 years; Mean BMI 21 kg/m²	24-h EE No adaptation	2 7	7,282 ± 230 kJ/day 7,834 ± 259 kJ/day	NS[a]
Verboeket-van de Venne and Westerterp (1993)	14 F; 20–58 years; Mean BMI 30 kg/m²	24-h EE 4 weeks	2 3–5	7,838 ± 416 kJ/day 7,867 ± 202 kJ/day	NS[a]
Verboeket-van de Venne et al. (1993)	10 M; 25–61 years; Mean BMI 25 kg/m²	24-h EE 6 days' adaptation	2 7	9.4 ± 0.2 MJ/day 9.4 ± 0.2 MJ/day	NS[a]
Taylor et al. (2001)	26 F; 36–51 years; BMI 38–42 kg/m²	24-h EE No adaptation	6 versus 2[b] 6 versus 2[c] 6 versus 4[d]	9.99 versus 9.95 MJ/day 9.27 versus 8.97 MJ/day 9.03 versus 9.13 MJ/day	NS[a] NS[a] NS[a]
Smeets et al. (2008)	14 F; Mean age 24.4 years; Mean BMI 23.2 kg/m²	24-h EE 3 days' adaptation	2[e] 3	8.2 ± 0.8 MJ/day 8.5 ± 0.6 MJ/day	NS[a]

This table presents a summary of studies that have investigated the effect of EF on TEE. This table gives some information about the study population, how TEE was measured, EF patterns used to compare the results, TEE results, and statistical significance of the results (Adapted from Bellisle et al. 1997)
EF eating frequency, *EE* energy expenditure, *TEE* total energy expenditure, *BMI* body mass index, *NS* not significant, *M* male, *F* female
[a]The correlation coefficients are not provided
[b]Without access to additional foods
[c]With access to additional foods
[d]The first two meals of the day were omitted to create a morning fast
[e]Lunch was omitted

several snacks may reduce appetite and as a consequence, decrease EI and body weight (Speechly et al. 1999). However, Cyr et al. (2007) shown that eating more frequently (three vs six times per day) does not have an impact on appetite. Fourth, higher levels of physical activity may promote a higher EF to meet increased energy requirements. As mentioned earlier, some studies on EF and body weight found that a higher EF could very well be a marker of a physically active lifestyle and may help in weight management (Duval et al. 2008a). However, as few EF studies have included a measure of physical activity, more studies are needed to confirm this finding.

178.3.5 Eating Frequency and Energy Expenditure

In the investigation of the association between EF and body weight and adiposity, both sides of the energy balance equation should be taken into account. TEE can be divided into three major components: thermic effect of food (TEF) (i.e., the increase in EE after ingestion of food), resting energy expenditure (REE), and PAEE. Most studies of EF and energy metabolism have failed to show any influence of EF on EE. Seven studies have investigated the effect of EF on TEE (see Table 178.5)

Table 178.6 Summary of studies that have investigated the effect of eating frequency on the thermic effect of food

Reference	Study population	Measure	EF pattern	TEF	Statistical significance
Belko and Barbieri (1987)	12 M; 18–34 years; Mean BMI 22 kg/m²	TEF for 10 h	2 4	43.3 ± 4.7 LO_2 43.4 ± 5.0 LO_2	NS[a]
Kinabo and Durnin (1990)	18 F; 18–34 years; Mean BMI 21 kg/m²	TEF for 6 h	High fat		
			1	356 ± 23 kJ	NS[a]
			2	340 ±16 kJ	
			Low fat		
			1	377 ± 30 kJ	NS[a]
			2	381 ± 27 kJ	
Tai et al. (1991)	7 F; 23–30 years; Mean BMI 20.8 kg/m²	TEF for 5 h	1 6	241 ± 34 kJ 174 ± 25 kJ	Significant negative correlation[a] G > N
Molnar (1992)	11 M + F; Mean age 12 y; obese	TEF for 6 h	1 3	11.9 ± 1.3%[b] 8.5 ± 0.7%[b]	Significant negative correlation[a] G > N
Verboeket-van de Venne et al. (1993)	10 M; 25–61 years; Mean BMI 25 kg/m²	TEF was calculated from 24-h EE measurement[c]	2 7	0.9 ± 0.1 MJ/d 0.9 ± 0.1 MJ/d	NS[a]
Leblanc et al. (1993)	6 M + F; 21–28 years; Mean BMI 23 kg/m²	TEF for 4 h	1 4	180 ± 16 kJ 259 ± 29 kJ	Significant positive correlation[a] N > G
Smeets et al. (2008)	14 F; Mean age 24.4 years; Mean BMI 23.2 kg/m²	TEF was calculated from 24-h EE measurement[c]	2[d] 3	0.86 ± 0.23 MJ/d 0.90 ± 0.30 MJ/d	NS[a]

This table presents a summary of studies that have investigated the effect of EF on TEF. This table gives some information about the study population, how TEF was measured, EF patterns used to compare the results, TEF results, and statistical significance of the results (Adapted from Bellisle et al. 1997)

EF eating frequency, *TEF* thermic effect of food, *EE* energy expenditure, *BMI* body mass index, *N* nibbling, *G* gorging, *NS* not significant, *M* male, *F* female

[a]The correlation coefficients are not provided

[b]Percent energy in meals

[c]Thermic effect of food was determined by subtracting sleeping metabolic rate from resting metabolic rate

[d]Lunch was omitted

(Taylor and Garrow 2001; Smeets and Westerterp-Plantenga 2008; Wolfram et al. 1987; Dallosso et al. 1982; Verboeket-van de Venne and Westerterp 1991, 1993; Verboeket-van de Venne et al. 1993). In these studies, rigorous measurements were made to compare subjects between a gorging (1–2 meals/day) or a nibbling (5–7 meals/day) eating pattern, including one study in which the 24-h whole-body calorimetry results were confirmed with DLW measurement of free-living EE (Verboeket-van de Venne et al. 1993). None of these studies reported any significant effect of EF on TEE. These studies provide evidence that there is no effect of meal pattern on TEE.

The results of the studies which specifically assessed TEF, as opposed to TEE, are inconsistent (see Table 178.6). While half of the studies found no significant differences between a gorging or a nibbling eating pattern (Belko and Barbieri 1987; Kinabo and Durnin 1990; Smeets and

Westerterp-Plantenga 2008; Verboeket-van de Venne et al. 1993), others reported either a higher TEF of food with lower EF (Tai et al. 1991; Molnar 1992) or the opposite (LeBlanc et al. 1993). Tai et al. (1991) found that the TEF of food was significantly higher in the low-EF group (one meal) than in the high-EF group (six meals) (7.68% vs 5.56%, respectively). Molnar et al. (1992) also found that the TEF (expressed as a percent of the energy ingested) was significantly higher with the single meal (11.9% ± 1.3%) than with the three small meals (8.5% ± 0.7%) in children. Inversely, LeBlanc et al. (1993) found an 8% lower TEF with one versus four meals a day. In light of the absence of effect of EF on TEE and the inconclusive evidence to support differences in TEF according to eating patterns, there is currently no reason to believe that changing EF would alter EE.

Concerning REE, it was found that higher EF has no effect on REE (Verboeket-van de Venne et al. 1993; Smeets and Westerterp-Plantenga 2008). Few of the published studies of EF and body weight have included a measure of the subjects' daily physical activity (Drummond et al. 1998; Duval et al. 2008a; Yannakoulia et al. 2007). As mentioned earlier in this chapter, it has been suggested that the inconsistent associations reported between EF, adiposity, and EI, especially in women, are due to differences in physical activity (Drummond et al. 1998; Duval et al. 2008a). Drummond et al. (1998) hypothesized that the absence of a relationship between EF and adiposity may be explained by the fact that frequent eaters may have higher EI due to higher physical activity levels. Duval et al. (2008a) found a positive correlation between EF and PAEE. Moreover, the results of this study showed that, after correction for PAEE and VO_{2peak}, the associations between adiposity and EF were no longer significant, which suggests that the relation between EF and body composition may be an artifact of higher PAEE and greater physical fitness. Therefore, higher EF resulting from higher physical activity and greater physical fitness could very well be a marker of a physically active lifestyle, at least in leaner persons. More studies will however be needed to confirm this finding.

178.3.6 Results' Discrepancies' Explanation

Methodological discrepancies have been proposed in order to explain some of the differences between studies in terms of the relationship between adiposity and EF: various definitions of eating occasions; under-reporting of food intake, especially among the obese; various methods of assessing food intake and body composition; and the fact that many studies did not take into account factors related to EE, especially physical activity. These methodological issues have been reviewed by Gatenby (1997).

As mentioned earlier in this chapter, the type of definition used to describe eating occasions may significantly influence the outcomes and interpretation of the studies. Inconsistencies in the definitions of EF used across studies, that is, time interval between two eating occasions versus predefined meal periods, make comparisons between studies hard to interpret and might have contributed to the heterogeneity of the findings.

Previous observations regarding eating patterns may also be affected by under-reporting of food intake. Since the Fabry et al. (1964) study, many studies have reported an inverse relationship between EF and body weight, suggesting that a "nibbling" pattern could help to prevent obesity. This notion has been put into question by the recognition of a high level of dietary under-reporting. In support of the latter idea, data from Summerbell et al. (1996) showed an inverse relationship between meal frequency and BMI in adolescents, which disappeared when dietary

Table 178.7 The associations between eating frequency and the variables related to energy balance

	EF correlates with…					
Population	Adiposity	TEE	REE	TEF	PAEE	Weight loss
Men	0 or –	0	0	0 or +	+	0
Women	0 or – (+ in postmenopausal women)	0	0	0 or – or +	+	0
Children	0 or –	No data	0	–	+	No data

This table presents a summary of the associations between EF and the variables related to energy balance. The associations are presented for three different populations (men, women, and children)

Plus (+) indicates significant relationship; negative (–) indicates significant inverse relationship; and zero (0) indicates non-significant relationship between EF and adiposity and EE and weight loss

EF eating frequency, *TEE* total energy expenditure, *REE* resting energy expenditure, *TEF* thermic effect of food, *PAEE* physical activity energy expenditure

records from under-reporters were excluded. Summerbell et al. (1996) has proposed that these findings may have repercussions for the interpretation of earlier studies, which did not screen for invalid dietary records. Research evidence indicates that under-reporting is particularly more frequent in overweight and obese persons (Livingstone and Black 2003; Heitmann and Lissner 1995), giving the impression that a low EF is positively related to adiposity. Even when under-reporters have been excluded, it was suggested that other factors, such as dietary restraint, have to be assessed. Indeed, in a study of a sample of 731 free-living teenagers, Crawley and Summerbell (1997) found an inverse relationship between meal and BMI, which was significant after exclusion of under-reporters. However, this relationship disappeared when dieting behavior and dietary restraint were taken into account. Under-reporting affects not only EI, but also the daily number of eating occasions, and snacks are particularly prone to under-reporting (Livingstone et al. 1990; Bellisle 2004).

The method used to assess food intake is another methodological issue which has been proposed to explain the contradictory results. However, while various methods have been used in EF studies, results do not differ consistently according to the method of assessment. Indeed, Metzner et al. (1977) (24-h diet recall) and Burley et al. (2002) (4-day food diary) found an inverse relation between EF and adiposity, whereas Drummond et al. (1998) (7-day food diary) and Yannakoulia et al. (2007) (3-day food diary) found no such relation in women. Most existing dietary-assessment methods are developed to analyze energy and nutrient intake but rarely eating patterns.

The techniques used to measure body fatness can have an effect on the relation between EF and body composition. Most studies of EF used BMI or included a measure of body composition using either skinfold-thickness measurements taken with calipers or underwater weighing to assess body fatness. Only two studies have used dual-energy X-ray absorptiometry for the measurement of body composition (Duval et al. 2008a; Yannakoulia et al. 2007). Duval et al. (2008a) found a negative relation between EF and adiposity, while Yannakoulia et al. (2007) did not find any relationship between EF and adiposity; conversely, Duval et al. (2008a) found a negative relation between EF, which was no longer significant after correction for PAEE and VO_{2peak}.

To obtain more accurate data, future studies need to identify under-reporters and individuals characterized by high levels of dietary restraint and exclude these from the analysis. They also need to use standardized criteria for defining EF in order to be able to compare results from different studies, and they should include an objective and valid measure of PAEE. The associations between EF and the variables related to energy balance are presented in Table 178.7.

178.4 Conclusion

Despite more than 40 years of research in this field, the influence of EF on body weight and adiposity is still not clear. The majority of the studies on EF and body weight status does not support the view that eating between meals, or snacking, leads to increases in weight and obesity. Indeed, some studies have reported a negative relation between EF and adiposity, whereas other studies found no association. The impact of EF on weight loss during energy restriction and on EE is more conclusive. Increasing EF does not promote greater weight loss. No difference in TEE has been documented as a function of daily eating occasions and weight loss is not facilitated by high EF. Several methodological discrepancies have been proposed to explain the differences observed between studies, especially the under-reporting of food intake and the lack of a standardized definition of key terms for EF.

Despite the inconclusive results, EF seems to be related with leanness in men (Drummond et al. 1998; Chapelot et al. 2006; Ruidavets et al. 2002). In women, many studies found no association or negative correlation between EF and adiposity, despite a higher EI (Burley et al. 2002; Drummond et al. 1998; Duval et al. 2008a; Yannakoulia et al. 2007). It was suggested that a higher EF could very well be a marker of a physically active lifestyle, at least in leaner persons. The combination of a high EF and increased physical activity may be an effective strategy for the control of body weight. In children, while some studies found no relationship between EF and body-weight status, the negative association between an increased EF and childhood overweight/obesity found by other investigators highlights the importance to assess eating pattern in childhood. Skipping meals might not be an appropriate approach for reducing the risk of obesity in children.

There is clearly a need to examine the relationship between EF and adiposity using both cross-sectional and longitudinal approaches. More long-term studies with sufficiently large sample sizes and using adequate and standardized methodologies are needed in order to provide accurate information on the association between eating occasions and body-weight control, which will be relevant for health-promotion strategies.

While the effects of EF on body-weight control are controversial, there is no evidence that dividing food intake in several daily eating episodes adversely affect body weight status. It was suggest that as long as EI is not greater than EE and that individuals eat only when they are hungry, splitting energy intake in several eating occasions over the day may be useful (Louis-Sylvestre et al. 2003). Louis-Sylvestre et al. (2003) also proposes that the EF pattern cannot be completely separated from the macronutrient composition of foods consumed. The composition of the food intake has also to be taken into account to be sure that low-energy, dense, high-carbohydrate foods are consumed. By itself, the currently available evidence does not support that increasing EF is associated to lesser adiposity, greater weight loss, or even the prevention of weight gain.

178.4.1 Applications to Other Areas of Health and Disease

There is some evidence that EF may be implicated in certain health parameters, notably diabetes, hypercholesterolemia, and colon cancer (Palmer et al. 2009). Studies investigating the metabolic effects of eating patterns have shown that, for a given EI, eating more frequently may lead to an improvement in blood lipid profile (decrease total and low-density lipoprotein (LDL) cholesterol), a better glucose tolerance, an improvement in insulin resistance, and a reduction of insulin concentration (Edelstein et al. 1992; Arnold et al. 1993; Jenkins et al. 1989, 1992, 1995; Gwinup et al. 1963a, b;

Carlson et al. 2007; Fabry et al. 1964). The lower levels of total and LDL cholesterol observed in more frequent eaters may help to reduce the risk of myocardial infarction (Fabry et al. 1968). However, more long-terms studies are needed to confirm these results. It should nonetheless be noted that results from at least one study suggest that the risk of colorectal cancer is proportional to EF (Gerhardsson de Verdier and Longnecker 1992).

Several physiological reasons have been proposed to explain the association between EF and diabetes risk indicators. It have been suggested that higher EF may lower insulin requirements and blood-glucose concentrations over the day (Jenkins et al. 1992). Indeed, Jenkins et al. (1992) have shown that spreading the nutrient intake throughout the day may promote glucose disposal resulting from a reduction of free-fatty acids' concentration. Another possible explanation is that more frequent eaters tend to produce less glucose-dependent insulinotropic polypeptide (GIP), which is an insulin stimulant and inhibits gastric emptying (Jenkins et al. 1990; Vitapole 2003). Thus, this decreased GIP production results in a decreased insulin secretion and a slowed rate of stomach emptying with consumption of smaller meals, which results in a slower rate of energy delivery to the intestine and less insulin required to control blood-glucose levels (Macdonald 1996; Doran et al. 1998).

Concerning the physiological mechanisms to explain the inverse associations between EF and total and LDL cholesterol, it was suggested that the reduction in insulin concentration observed in more frequent eaters may have an impact on the reduction of the enzyme hydroxymethylglutaryl-CoA (HMG-CoA) reductase, responsible for hepatic cholesterol synthesis (Jenkins et al. 1989). A decrease in cholesterol synthesis increases LDL receptors, resulting in lower concentrations of total and LDL cholesterol (Jenkins et al. 1989). A nibbling eating pattern may also give more opportunities to remove cholesterol, which is normally removed in the postprandial phase (Mann 1997).

Summary Points

- There is a lack of standardized definition of eating frequency. Two types of definition are normally reported to categorize eating frequency in the literature: predefined eating periods and time interval between two eating occasions.
- The 24-h dietary recall and the food record/diary are mostly used to assess eating frequency.
- Under-reporting has been recognized as an important methodological issue in the relation between eating frequency and body weight. Overweight, obese, and diet-restrained subjects are more likely to under-report their food intake.
- The association between eating frequency and body-weight status is not clear. Studies in both adults and children have either failed to find a significant relationship between eating frequency and adiposity or have found an inverse relationship.
- A high eating frequency may be associated with an increased carbohydrate: fat ratio and a reduction in hunger, which may help for body-weight control. A high eating frequency may also help to spread the energy intake over the day.
- The impact of eating frequency on weight loss during energy restriction and on energy expenditure is more conclusive. No difference in total energy expenditure has been documented as a function of daily eating occasions, and weight loss is not facilitated by high eating frequency.
- Physical activity seems to be related with a higher eating-frequency pattern. Subjects who eat more frequently tend to have a physically active lifestyle.
- Several methodological discrepancies have been proposed to explain some differences observed between studies: various definitions of eating occasions, under-reporting of food intake, various methods of assessing food intake and body composition, and the lack of physical-activity measurement.

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