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WEIGHT LOSS AND SEXUAL ACTIVITY IN ADULT OBESE INDIVIDUALS: ESTABLISHING A CAUSAL LINK*†

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Abstract

Obesity may not only be linked to undesirable health outcomes but also to limitations in sexual life. The present paper aims to assess whether there is a causal relationship between weight loss and sexual activity in adult obese individuals. To address the endogeneity of weight loss that is likely to result in biased estimation results, the analysis is based on data from a randomized field experiment. In this experiment financial weight-loss rewards were offered to a random subgroup of participants and can be used as exogenous source of weight variation in an instrumental variables approach. Estimation results indicate that for obese males loosing weight increases the probability for being involved in a sexual relationship. Conditional on having already lost some weight, a further reduction in obesity also increases the frequency of sexual intercourse.

JEL codes: *I10, I18, J28, J65*
Keywords: *obesity, sexual partnership, frequency of intercourse, randomized trial, weight-loss incentives.*

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1 Introduction

A close link of a fulfilling sex life and general life satisfaction is well documented in the literature (e.g. Woloski-Wruble et al., 2010; Schafer et al., 2013). Impairments in sexual life thus are likely to have a strong negative impact on individual happiness and life satisfaction. One possible reason for limitations in sexual life is obesity; see Larsen et al. (2007) for a review of the medical literature focussing on the association of obesity and sexual dysfunction such as erectile dysfunction. Though the majority of analyses reviewed by Larsen et al. (2007) find a positive association, the evidence is still mixed.[1] Taking a less physiological oriented perspective and considering deficits in sexual life beyond sexual dysfunctions, Kolotkin et al. (2006) list 'lack of enjoyment', 'lack of desire', 'difficulties with performance', and 'avoidance of sexual encounters' as examples for obesity related impairments of sexual life. Thus, besides undesirable general health outcomes, obesity may have a more direct detrimental effect on happiness and life satisfaction that operates through an unsatisfactory sex life.

The non-medical, health-economics oriented literature has taken a very different view on the link of body weight to sexual life. This relatively small literature (Cawley, 2001; Halpern et al., 2005; Cawley et al., 2006; Sabia and Rees, 2011; Ali et al., 2014; Neymotin and Downing-Matibag, 2014) focusses on individuals of very young age, adolescents in particular. Due to the focus on this special age group, sexual activity is not primarily interpreted as one facet of a happy and fruitful life. It is rather associated with premature initiation to sex, potentially exerting detrimental effects on adolescents' later lives. For female adolescents Sabia and Rees (2008) find a causal and detrimental effect of early sexual intercourse on psychological well-being. Ali et al. (2014) allude to disease and pregnancy risks teenagers take when having sex early in their lives, suggesting that a postponed initiation to sexual activities might be a beneficial side-effect of teenage overweight.

The contribution of the present paper is to (i) conduct an analysis that focusses on adult individuals, for whom the above line of argument does not apply and whose sexual behavior, most likely, differs from the behavior of the age group studied by the above cited literature. Moreover, unlike the majority of the medical literature, our focus is (ii) on (self-reported) sexual activity rather than specific sexual dysfunctions such as erectile dysfunction. This is important as obesity related limitations in sex life may often be unrelated to any physiological deficit but can possibly be attributed to social and psychological body-weight related factors, such as being less attractive

[1] Especially for women, for which 'sexual dysfunction' is less clearly defined than for men and for which the number of studies is much smaller, several analyses fail in establishing an association of sexual dysfunction and body weight (e.g. Adolfsson et al., 2004; Kolotkin et al., 2006).

to a potential partner, a lack of self confidence when dating, or less enjoyment in and desire for sex. Finally, the present analysis contributes to the existing evidence by (iii) establishing a causal effect of weight-loss on sexual activity as opposed to finding a mere correlation in the data.

Focussing on the non-medical strand of the literature, causality in the link between body weight and sex life has not always attracted much attention. Halpern et al. (2005), for instance, estimate that one BMI unit less increases the probability of being involved in a romantic relationship (with or without sexual intercourse) by 6-7 percent in adolescent girls. Using Add Health (National Longitudinal Survey of Adolescent Health; Harris, 2013) data,[2] a US longitudinal school-based survey, Cawley et al. (2006) find that for obese girls the odds of initiation to sexual intercourse are just 32 percent of the odds of normal-weight girls. However, both analyses do not account for unobserved heterogeneity. Hence, the striking results may well be attributed to unobserved confounding factors, such as personal character traits, that are relevant for both obesity related behavior (eating habits, physical activity) and mating behavior. Numerous studies from the medical literature (see Larsen et al., 2007) likewise are concerned with the association of overweight and impairments in sex life rather than with a causal relationship.

More recent papers address possible endogeneity by the use of instrumental variables (IV) estimation. Also analyzing data from Add Health and using siblings' BMI and mother's obesity status as instruments for the respondents' body weight, Sabia and Rees (2011) find that a one unit increase in BMI reduces the probability ob being sexually active by 3.5 percentage points in girls aged 14 to 17. In contrast, no significant effect is found for boys. Rather, the point estimate for boys bares the opposite sign in several specifications. Ali et al. (2014) take a similar approach by instrumenting body weight with maternal obesity status. For white girls – but not for blacks – they find that higher body weight or being obese significantly lowers the probability of having had sex or having been involved in a romantic relationship.

Though both papers carefully discuss the validity of the instruments used and argue that including a wide range of covariates does capture any possible direct effects from mother's body weight to the child's sexual behavior, one may still doubt whether mother's – and other relatives' – body weight is a valid instrument. One concern is that not only body weight but also sexual behavior – or at least attitudes towards it – may be intergenerationally transmitted from the mother to her children (e.g. Taris, 2000). If so, mother's own sexual behavior represents another channel through which maternal body weight influences children's sex life, given that body weight matters for sexual behavior. Another concern with respect to instrument validity is the social en-

[2] When alternatively using the NLSY (National Longitudinal Survey of Youth) Cawley et al. (2006) cannot confirm their key Add Health based findings.

vironment children share with their mothers and siblings. It may strongly influence both body weight and attitudes towards sex for both mothers and children and, most likely, cannot entirely be controlled for by including covariates in the analysis.

While following Sabia and Rees (2011) and Ali et al. (2014) in relying on instrumental variables for establishing a causal link between body-weight and sexual behavior, we do not use maternal body weight as instrument. Rather, in our analysis identification rests on exogenous variation in BMI that was artificially induced in a randomized field experiment. More precisely, we use data that originate from a randomized trial that was conducted to evaluate the effectiveness of financial incentives for weight loss (Augurzky et al., 2012, 2014). In this experiment individuals in the intervention groups were exposed to financial incentive for loosing body weight, while control group members were not. Hence following Reichert (2015) treatment status can serve as an instrument for the change in body weight. Besides using different instruments and focussing on adult individuals, our analysis materially deviates from Sabia and Rees (2011) and Ali et al. (2014) by only considering obese individuals. That is, the empirical analysis is not concerned with the question of whether being overweight, or even obese,[3] has adverse effects on sex life. Rather, we are interested in the question of whether – even moderate – weight loss in obese individuals makes a difference for their sexual lives.

The strategy for identification of the present analysis is related to the approach of Esposito et al. (2004). This medical study also relies on data from a randomized field experiment with obese participants. In this study the intervention was not exposition to financial incentives but guidance on how to loose weight combined with weight monitoring through monthly group sessions. Yet, rather than identifying a causal effect of weight loss, Esposito et al. (2004) estimate a reduced form effect by comparing post-intervention IIEF (International Index of Erectile Function) scores between the intervention and the control group. The statistically significant advantage in IIEF found for the intervention group nevertheless provides striking evidence for body-weight mattering for sexual dysfunctions in obese. However, by focussing on erectile dysfunction alone, Esposito et al. (2004) may miss out other obesity related impairments of sexual life. By considering two different measures of sexual activity our analysis takes a broader perspective on the link between obesity and sex life.

The remainder of this paper is organized as follows. The subsequent section 2 introduces the data and describes the experiment the data originates from. Section 3 discusses the econometric model and section 4 presents the estimation results for the basic model. In section 5 alternative

[3] The WHO defines overweight and obesity as the body mass index (BMI, body weight per squared body height $[kg/m^2]$) reaching the threshold values of 25 and 30, respectively (World Health Organization, 2000).

model specifications and estimation results are discussed. Section 6 summarizes and discusses the main findings and concludes.

2 Data

2.1 The Experiment

The data used in this analysis originate from a large scale, four-phase, randomized field experiment that is described in more detail elsewhere (Augurzky et al., 2012). The experiment was conducted between March 2010 and July 2013. Roughly 700 obese individuals where recruited in the period March 2010 to August 2011. Recruitment took place in four rehabilitation clinics in the south-west of Germany (Bad Mergentheim, Bad Kissingen, Isny, and Glottertal). Only for a minor group of participants obesity was the immediate reason for their rehab stay. Yet, many were sent to the clinic because of health deficits that are connected with overweight or obesity such as chronical back pain, for instance. The participating rehab clinics are operated by the German Pension Insurance (DRV), Baden-Württemberg section. For this reason all patients are insured with DRV and the ultimate aim of treatment at the rehab clinics is either to preserve or to restore patients' workableness. Shortly after clinic admission the physician in charge approached all patients who had a BMI of 30 or above and complied with the further admission criteria[4] and asked them for voluntary participation in the experiment. Shortly before discharge from the clinic, after a typically three weeks stay, all participating individuals were set an individual weight-loss target by the physician in charge that they were prompted to realize within four months. The physicians were advised to choose a weight-reduction target of about six to eight percent of current body weight, but where free in setting a target they regarded medically appropriate given the specific case. Subsequently the participants were randomly assigned to two incentive groups ($incentive\,150_{1\text{-}4}$ and $incentive\,300_{1\text{-}4}$)[5] and one control group ($incentive\,0_{1\text{-}4}$). Members of the former two groups were promised €150 and €300, respectively, for realizing (or exceeding) their individual weight-loss target within four months, while members of the control group were not exposed to any financial incentives for reducing body weight. Members of $incentive\,150_{1\text{-}4}$ and $incentive\,300_{1\text{-}4}$ who fail in fully complying with the scheduled weight loss but managed to reduce

[4] Age between 18 and 75 years, resident of the federal state of Baden-Württemberg, sufficient German language skills, no pregnancy, no psychological and eating disorders, no substance abuse, no seriously illnesses (specified list of diseases).

[5] To keep notation simple we omit the index i indicating individuals. Numerical subscripts refer to months since rehab discharge. Thus, variables indexed with a simple numerical subscript refer to a certain point in time; e.g. BMI_0 denotes BMI measured at rehab discharge while BMI_4 denotes BMI measured four months later, i.e. by the end of the weight-loss phase. Variables indexed with a bipartite numerical subscript separated by a short hyphen refer to a time span; e.g. for $incentive\,300_{1\text{-}4}$ the observation period is month 1 to month 4 (including months 1 and 4), i.e. the entire four months weight-reduction phase.

their body weight by at least 50 percent of the contractual target were awarded proportionally to the degree of target achievement. That is a member of *incentive* $300_{1\text{-}4}$ with body weight of 100 kg at clinic discharge and a weight-loss target of 7 kg would not have received any financial rewards if she were weighed more than 96.5 kg at the end of the weight-reduction phase. She would have received the full premium of € 300 if they were weighed 93 kg or less. If she were weighed w kg, with $93 < w \leq 96.5$, she would have received € $300 \cdot (100-w)/7$.

The weigh-in at the end of the weight-reduction phase – and all further weigh-ins – were carried out at assigned pharmacies. While a pharmacy as close as possible to the participants place of residence was typically selected by the experimenters, the test persons could not actively influence to which particular pharmacy they were sent.[6] Thus, the location of weigh-in was exogenous to the participants. All participants received a show-up fee of € 25 for attending the weigh-in and (partially) successful incentive group members received the respective reward. Shortly after the weigh-in, all participants – irrespective of group membership in the weight-reduction phase and irrespective of success – were prompted to comply with their target weight by the end of a subsequent six months weight-maintenance phase.[7] Yet, conditional on success in the weight reduction phase, a second randomization took place at the same time. Participants who had lost at least 50 percent of their contractual weight-loss target were randomly assigned to two intervention groups (*incentive* $250_{5\text{-}10}$, *incentive* $500_{5\text{-}10}$) and one control group (*incentive* $0_{5\text{-}10}$). The former two could gain up to € 250 and € 500, respectively, if they were weighed their target weight or less ten months after rehab discharge. For those who did not fully comply with the target weight, the actual reward was calculated using the same rule as described above. No rewards were promised to members of the control group. Individuals who were not successful in the weight-reduction phase were hence effectively assigned to the control group.

Six month later, i.e. ten months after rehab discharge, another weigh-in took place under identical conditions. Yet, at this point in time the incentive scheme was terminated and no further randomization took place. However, all participants were still requested to comply with their target weights and another weigh-in was announced to take place after another twelve months. This final year serves the follow-up phase. See Figure 1 for the time line of the entire experiment.

By the end of each of the four phases, the participants had to answer a detailed questionnaire. The final one, which was sent to the participants 22 months after rehab discharge, is of major importance to the present analysis as it is the only one that includes questions concerning the participants sex life. Yet, only for participants with even identification number – i.e. for a fifty

[6] Any pharmacy was contacted by the experimenter prior to sending participants there for the weigh-in. If a pharmacy denied cooperation – though it was remunerated for its effort – a more distant pharmacy had to be assigned.

[7] For not fully successful individuals the 'weight-maintenance phase' was effectively another weight-reduction phase.

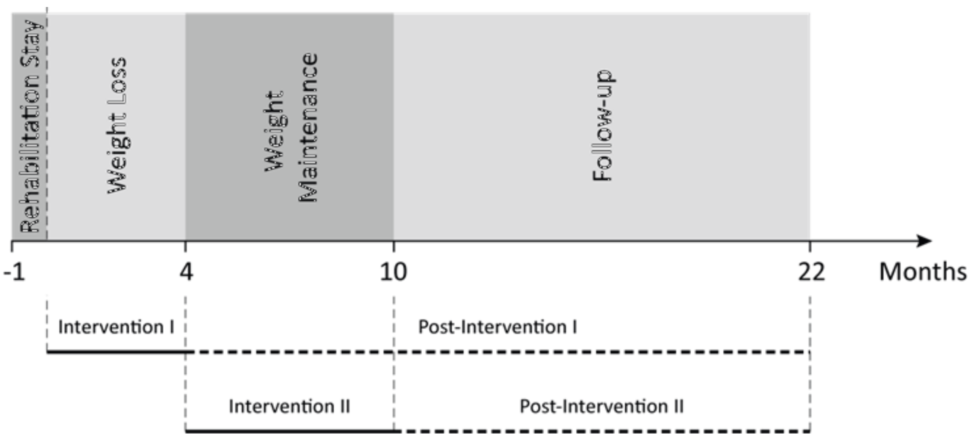

Figure 1: Time line of the four-phase experiment.
Source: Augurzky et al. (2014).

percent random sample[8] – the questionnaire included these delicate questions. The reason for this was to reduce the risk of making too many individuals drop out by asking them – possibly displeasing – questions about their sex lives. However, this concern proved immaterial as the drop out rate virtually did not differ between individuals with even and with odd identification number.

The experiment population was subject to significant sample attrition. 697 individuals started the weight-reduction phase after rehab discharge. 177 participants dropped out during the weight-reduction phase, i.e. they did not show up at the weigh-in after four months, leading to only 520 individuals who entered the weight-maintenance phase. In this phase another 109 individuals dropped out. The follow-up phase was also subject to some sample attrition reducing the number of individuals for whom weight information is available by the end of the experiment to 316. Among these 174 were asked questions regarding sex life. Only 17 denied any kind of information on their sex lives. This corresponds to a rate of item-non-response of less than 10 percent, which is remarkably low compared to many surveys addressing sexual behavior (cf. Fenton et al., 2001).

2.2 Variables

In the final questionnaire, which participants had to fill in 22 months after rehab discharge, they were asked two questions regarding their sex lives, (i) whether being involved in a sexual relationship and (ii) how frequently they have sexual intercourse. Both questions refer to the previous twelve month that is to the follow-up phase of the experiment. While the fist question had to be

[8]As the individual identifiers were issued as clinic specific sequential numbers, for each participant the odds for an even or an odd id-number were fifty-fifty.

Table 1: **Joint and Marginal Distribution of Dependent Variables**

	frequency of sexual intercourse					**marginal distribution**$^{+}$		
	never	occasionally	monthly	weekly	daily	all	males	females
sexual relationship: no	32	9	1	0	0	**45**	20	25
yes	0	25	32	48	4	**111**	83	28
marginal distribution^{+}: all	**32**	**35**	**33**	**48**	**4**	**157**	103	53
males	11	26	22	37	3	99		
females	21	9	11	11	1	53		

Notes: $^{+}$Due to item non response, values do not exactly sum up. 157 responses to (at least) one of the two questions regarding sex life; 156 responses to question about sexual relationship; 152 responses to question about frequency of intercourse.

answered by yes or no, the latter allowed for answers on a five categories scale, more precisely 'never', 'occasionally', 'at least once a month', 'at least once a week', '(almost) daily'. Hence we can use two different measures of sexual activity as dependent variables, a binary indicator ($sexpartner_{11\text{-}22}$) and an ordered categorial one ($sexfrequency_{11\text{-}22}$). 156 and 152, respectively, participants answered these questions.[9] For model estimation, we reduced the number of categories for the latter variable to three ('never', 'occasionally', 'regularly') where the third category combines having sex monthly, weekly or (almost) daily. The reason for this is the relatively small sample of observations that – for some model specifications – renders the number of individuals that are observed in some of the original categories very small. Table 1 displays the joint distribution of $sexpartner_{11\text{-}22}$ and $sexfrequency_{11\text{-}22}$ (full set of categories). The information regarding the two measures seems to be mutually consistent, as no respondent who reports not to have had sex in the previous year, reports having been involved in a sexual partnership for the same period. The data also indicates that the respondents distinguish between living together with a partner and having a sexual relationship. Though both variables are highly positively correlated, roughly one in ten of those who live with a partner report not to live in a sexual partnership. None of these individuals reports having sex more often than occasionally.

The dependent variables are observed for the final phase of the experiment (month 11 to month 22). We measure the key explanatory variables prior to this and use the change in BMI measured between rehab discharge and the end of the weight maintenance phase, denoted $\Delta\, BMI_{1\text{-}10}$, as key explanatory variable.[10] For an alternative specification of the model, we use weight change over the entire experiment duration ($\Delta\, BMI_{1\text{-}22}$) as explanatory variable. Thus, in this specification we allow for the measuring periods for the dependent variable and the key regressor to overlap; see Tables 13 and 14 in the Appendix for results which do not differ much from those for the preferred specification.

[9]While a single individual answered the question concerning the frequency of sexual intercourse but provided no information on involvement in a sexual relationship, for five individuals the provision of information exhibits the reverse pattern.

[10]One may think of using the level of the BMI (at the end of the maintenance phase) instead of its change. Yet, as long as BMI at rehab discharge is controlled for, both model variants are fully equivalent.

The small number of observations precludes specifying a rich regression model with numerous controls. Hence only age and sex[11] as basic socioeconomic characteristics enter the model. Besides these, BMI at rehab discharge (BMI_0) and an indicator for living together with a partner at the time of rehab discharge ($together_0$) enter the regression model. We include the former to capture the effect of pre-intervention body weight which is most likely endogenous and for which no instruments are available.[12] The latter we include as the closest substitute available for pre-intervention values of the dependent variable, which is not observed in the data. We also estimated specifications with age squared and body height – which might matter for sexual attractiveness – entering as additional controls. Both proofed statically insignificant and including them has very little effect on the estimation results. So we stick to a more parsimonious specification. Table 2 displays key descriptives for the explanatory variables.

The key concern to the present analysis is the possible endogeneity of both body weight and its change over time. The validity of estimates obtained from naively regressing measures of sexual activity on body weight are subject to concern of endogeneity bias for several reasons. First, unobserved individual characteristics may have an effect on either variable. One may hypothesise that individuals with high self-esteem are more successful in finding a partner and are also less vulnerable to overeating and obesity. This argument also applies if a change in body weight rather than its level is considered. Self-confidence and self-esteem are possibly decisive for being successful, when seriously trying to get less obese. Yet, a different channel through which individual heterogeneity may generate a spurious correlation is the individual preference for physical pleasures. If such preferences are strong, one is likely to have more desire for both having sex and calorie intake. Second, reverse causality might also be a source of endogeneity bias. One such channel is sexual frustration-induced overeating. Yet, one may also argue that being satisfied with his or her sex life reduces the pressure to comply with ideals of beauty, rendering obesity less costly in psychological terms.

As we observe the dependent variables only once, fixed effects estimation is not an option for eliminating unobserved heterogeneity. Moreover, the threat of bias due to reverse causality is not fully eliminated via regressing $sexpartner_{11\text{-}22}$ and $sexfrequency_{11\text{-}22}$ on a lagged measure of body weight ($\Delta\, BMI_{1\text{-}10}$). While using a lagged regressor evidently rules out direct reverse causality, lagged body weight may still be influenced by past sex life. And, provided that sexual behavior exhibits some kind of persistency over time, unobserved past sex life is directly linked to the

[11]For six individuals, who did not state their gender in a questionnaire, sex is imputed on basis of individuals characteristics such as body height and labor market status. Excluding these few individuals from the estimation sample, has hardly any effect on the estimation results.

[12]For this reason, the coefficient of BMI_0 is most likely estimated with bias. Yet, as our instruments for $\Delta\, BMI_{1\text{-}10}$ are orthogonal to BMI_0, the bias does not carry over to the coefficient of primary interest.

Table 2: **Descriptive Statistics for Estimation Sample by Gender**

	Mean	**S.D.**	**Median**	**Min.**	**Max.**
			All		
dependent variables:					
$sexpartner_{11\text{-}22}$	0.712	0.455	1.000	0.000	1.000
$sexfrequency_{11\text{-}22}$	1.349	0.808	2.000	0.000	2.000
$together^{+}_{22}$	0.637	0.482	1.000	0.000	1.000
explanatory variables:					
$\Delta\, BMI_{1\text{-}10}$	−1.229	2.596	−1.130	−15.347	3.774
$\Delta\, BMI^{+}_{1\text{-}22}$	−0.318	3.305	−0.080	−18.114	10.040
$\Delta\, BMI^{+}_{5\text{-}10}$	0.448	1.604	0.362	−8.424	4.181
age	50.166	7.982	51.000	21.000	68.000
female	0.338	0.474	0.000	0.000	1.000
$together_0$	0.675	0.470	1.000	0.000	1.000
BMI_0	35.831	5.087	34.816	28.441	60.221
$together^{+}_4$	0.656	0.477	1.000	0.000	1.000
BMI^{+}_4	34.153	5.149	33.391	22.857	60.672
$success^{+}_4$	0.624	0.486	1.000	0.000	1.000
instrumental variables:					
$incentive\,150_{1\text{-}4}$	0.204	0.404	0.000	0.000	1.000
$incentive\,300_{1\text{-}4}$	0.236	0.426	0.000	0.000	1.000
$incentive\,250_{5\text{-}10}$	0.312	0.465	0.000	0.000	1.000
$incentive\,500_{5\text{-}10}$	0.357	0.481	0.000	0.000	1.000
$pharmacy\ nearby^{+}_{1\text{-}22}$	0.682	0.467	1.000	0.000	1.000
			Males		
dependent variables:					
$sexpartner_{11\text{-}22}$	0.806	0.397	1.000	0.000	1.000
$sexfrequency_{11\text{-}22}$	1.515	0.691	2.000	0.000	2.000
$together^{+}_{22}$	0.683	0.468	1.000	0.000	1.000
explanatory variables:					
$\Delta\, BMI_{1\text{-}10}$	−1.256	2.676	−1.162	−15.347	3.774
$\Delta\, BMI^{+}_{1\text{-}22}$	−0.526	3.362	−0.299	−18.114	5.495
$\Delta\, BMI^{+}_{5\text{-}10}$	0.498	1.573	0.393	−8.424	4.181
age	50.183	7.601	50.000	21.000	68.000
female	0.000	0.000	0.000	0.000	0.000
$together_0$	0.731	0.446	1.000	0.000	1.000
BMI_0	35.164	4.793	34.414	28.441	50.039
$together^{+}_4$	0.692	0.464	1.000	0.000	1.000
BMI^{+}_4	33.411	4.634	32.747	22.857	48.001
$success^{+}_4$	0.635	0.484	1.000	0.000	1.000
instrumental variables:					
$incentive\,150_{1\text{-}4}$	0.173	0.380	0.000	0.000	1.000
$incentive\,300_{1\text{-}4}$	0.279	0.451	0.000	0.000	1.000
$incentive\,250_{5\text{-}10}$	0.308	0.464	0.000	0.000	1.000
$incentive\,500_{5\text{-}10}$	0.327	0.471	0.000	0.000	1.000
$pharmacy\ nearby^{+}_{1\text{-}22}$	0.663	0.475	1.000	0.000	1.000
			Females		
dependent variables:					
$sexpartner_{11\text{-}22}$	0.528	0.504	1.000	0.000	1.000
$sexfrequency_{11\text{-}22}$	1.038	0.919	1.000	0.000	2.000
$together^{+}_{22}$	0.547	0.503	1.000	0.000	1.000
explanatory variables:					
$\Delta\, BMI_{1\text{-}10}$	−1.177	2.455	−0.830	−7.249	3.048
$\Delta\, BMI^{+}_{1\text{-}22}$	0.090	3.182	0.033	−6.732	10.040
$\Delta\, BMI^{+}_{5\text{-}10}$	0.351	1.676	0.137	−3.366	4.147
age	50.132	8.757	51.000	21.000	63.000
female	1.000	0.000	1.000	1.000	1.000
$together_0$	0.566	0.500	1.000	0.000	1.000
BMI_0	37.140	5.429	35.417	29.714	60.221
$together^{+}_4$	0.585	0.497	1.000	0.000	1.000
BMI^{+}_4	35.611	5.808	34.297	27.690	60.672
$success^{+}_4$	0.604	0.494	1.000	0.000	1.000
instrumental variables:					
$incentive\,150_{1\text{-}4}$	0.264	0.445	0.000	0.000	1.000
$incentive\,300_{1\text{-}4}$	0.151	0.361	0.000	0.000	1.000
$incentive\,250_{5\text{-}10}$	0.321	0.471	0.000	0.000	1.000
$incentive\,500_{5\text{-}10}$	0.415	0.497	0.000	0.000	1.000
$pharmacy\ nearby^{+}_{1\text{-}22}$	0.717	0.455	1.000	0.000	1.000

Notes: Statistics for 157 individuals who provide information on $sexpartner_{11\text{-}22}$ or $sexfrequency_{11\text{-}22}$. $^{+}$ Variable used in alternative model specification/robustness check.

left-hand-side variable, generating a spurious correlation between the regressand and $\Delta\, BMI_{1\text{-}10}$. Given the lack of information about how the respondents' sex life develops over time, instrumental variables estimation is the first choice for identifying a causal relation. As the data used in this analysis originates from a randomized field experiment described in section 2.1, it includes variables well suited for being used as instrumental variables. More precisely, these variables are $incentive\,150_{1\text{-}4}$, $incentive\,300_{1\text{-}4}$, $incentive\,250_{5\text{-}10}$, and $incentive\,500_{5\text{-}10}$, i.e. the indicators for randomly assigned group membership in the two intervention phases of the experiment. While exogeneity is guaranteed by the experimental design[13], explanatory power for the endogenous regressor $\Delta\, BMI_{1\text{-}10}$ has been established elsewhere in the literature (Augurzky et al., 2012, 2014). In other words, the analyses cited above clearly find that being exposed to financial incentives for weight loss makes obese individuals loosing body weight. Table 2 displays descriptive statistics for the group indicators ($incentive\,150_{1\text{-}4}, \ldots, incentive\,500_{5\text{-}10}$) for males and females, and for the pooled sample. Though the randomization design allocated equal probability to each experimental group, the mean values deviate substantially from 1/3. This can be explained by two reasons: (i) Drop-out from the experiment was more frequent in the control groups where no financial rewards can be earned; (ii) individuals who did not (sufficiently) comply with contractual the weight loss after four months were – without randomization – directly assigned to the no incentive group in the weight maintenance phase.

3 Estimation Procedure

The econometric model rests on a linear equation that links a latent dependent variable to the key regressor $\Delta\, BMI_{1\text{-}10}$, the control variables, and a normally distributed error.[14] This leads to a conventional binary probit model for explaining $sexpartner_{11\text{-}22}$ and an ordered probit model for explaining $sexfrequency_{11\text{-}22}$.

As discussed above, the potential endogeneity of $\Delta\, BMI_{1\text{-}10}$ is the key challenge to the empirical analysis that is addressed via the use of instrumental variables (IV). Since the latent dependent variables are not observed, conventional linear instrumental variables estimation, such as two-step least squares, is not an obvious choice for the estimation procedure. For this reason we rely on the assumption of joint normality for identification and specify a control function model.

[13]See section 5 for further discussion of instrument validity.

[14]These latent counterparts to $sexpartner_{11\text{-}22}$ and $sexfrequency_{11\text{-}22}$ could be labelled 'inclination and opportunity to live in sexual relationship' and 'inclination and opportunity to have sexual intercourse', respectively. It is important to note that, unlike other behaviors, it is not just individual desire for sex that makes an individual sexually active but also his or her attractiveness to potential partners (and the availability of the latter). Since we cannot distinguish between both in the empirical analysis, we abstain from formulating a more complex econometric model that explicitly takes account of these different aspects.

The control function is equivalent to the instrumental equation in the linear IV-model besides that joint normality is explicitly assumed and used for identification. This distributional assumption allows for joint estimation of all model parameters using maximum likelihood (ML). That means, estimation is carried out in a single step. Deriving a log-likelihood function that is easily dealt with in the optimization procedure rests on expressing the joint likelihood as the product of (i) the probability of the observed outcome conditional on the endogenous regressor and (ii) the density of the endogenous regressor conditional on the instruments. See Wooldridge (2002, p. 476) for ML estimation of the binary probit model with an endogenous regressor. This control function approach is straight forward generalized to related models such as ordered probit required for estimating the model variant with $sexfrequency_{11\text{-}22}$ on the left-hand-side. Moreover, due to joint estimation, individuals for which the dependent variables are not observed but the endogenous regressor is observed contribute to the log-likelihood function and enter the estimation sample. Roodman (2011) discusses various control function models that involve a linear index and jointly normal errors and introduces a software component that implements these models.[15]

One may think of estimating the model more conventionally using two-stage least squares, in order to avoid strong distributional assumptions. For the model explaining $sexpartner_{11\text{-}22}$ this is instrumental variables estimation of a linear probability model.[16] For the model explaining $sexfrequency_{11\text{-}22}$ this approach is less straight forward as it requires interpreting the ordered categorial left-hand-side variable to be cardinal. For this reason we stick to the parametric non-linear model as our preferred specification. Yet, in the Appendix we also report results for the linear model, which in qualitative terms do not differ much from their probit counterparts; see Tables 15, 16, 17, and 18.

4 Estimation Results for the Basic Model

In this section we discuss estimation results for the models described above. Table 3 displays results for the model variant that uses $sexpartner_{11\text{-}22}$ as dependent variable, while Table 4 displays results for the model that explains $sexfrequency_{11\text{-}22}$. Besides a pooled model that considers men and women, we discuss results for a stratified specification, as the determinants of sex life are likely to differ substantially between both genders. Starting with the question of what renders a sexual relationship more likely for males, Table 3 (upper panel, left columns) indicates that age does not have a significant effect. Not surprisingly, those who lived with a partner at time zero

[15]This Stata® ado-file, called *cmp* (conditional mixed process), is used in the present application.

[16]However, the linear probability model is – implicitly – subject to strong distributional assumptions too, and has therefore been criticized in the literature (e.g. Horrace and Oaxaca, 2006).

Table 3: **Involved in a Sexual Relationship (estimated coefficients)**

	Males		Females		All	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexpartner_{11\text{-}22}$)						
$\Delta\, BMI_{1\text{-}10}$	-0.194^{**}	0.086	-0.007	0.212	-0.166^{*}	0.096
age	0.009	0.020	-0.009	0.023	-0.007	0.015
female	–	–	–	–	-0.672^{**}	0.254
$together_0$	1.313^{**}	0.381	1.511^{**}	0.555	1.508^{**}	0.280
BMI_0	-0.053^{*}	0.030	0.002	0.036	-0.045^{*}	0.025
constant	1.212	1.533	-0.365	1.745	1.675	1.194
control function (dependent variable: $\Delta BMI_{1\text{-}10}$)						
$incentive\ 150_{1\text{-}4}$	-0.701^{*}	0.410	-0.806^{+}	0.511	-0.762^{**}	0.328
$incentive\ 300_{1\text{-}4}$	-0.960^{**}	0.408	-1.231^{**}	0.484	-1.077^{**}	0.322
$incentive\ 250_{5\text{-}10}$	-2.753^{**}	0.412	-1.318^{**}	0.499	-2.289^{**}	0.322
$incentive\ 500_{5\text{-}10}$	-2.049^{**}	0.402	-1.784^{**}	0.527	-1.877^{**}	0.326
age	0.004	0.021	-0.007	0.023	0.001	0.016
female	–	–	–	–	0.076	0.271
$together_0$	-0.485	0.381	0.266	0.420	-0.167	0.290
BMI_0	-0.082^{**}	0.028	0.012	0.029	-0.046^{**}	0.021
constant	3.510^{**}	1.640	-0.152	1.643	2.052^{*}	1.194
ancillary parameters						
σ (control function error S.D.)	2.654^{**}	0.114	2.256^{**}	0.134	2.556^{**}	0.090
ρ (error correlation)	0.536^{**}	0.248	-0.443	0.434	0.268	0.276
# of observations (over all)	271		141		412	
# of observations (main equation)	103		53		156	
log likelihood	-684.0		-339.5		-1034.1	
instrument relevance (p-value, joint sig. instruments)	0.000		0.000		0.000	
sample split (p-value, LR-test)	–		–		0.069	

Notes: ** significant at 5%; * significant at 10%; $^{+}$ significant at 15%.

(experiment start) are more likely to have a sexual partner one or two years later. Estimation results yield also a significantly negative association with initial BMI. Yet, this coefficient does not isolate a causal relationship but is likely to also capture the influence of unobserved individual heterogeneity.

The key coefficient is rather attached to $\Delta\, BMI_{1\text{-}10}$ and is highly significant (p-value: 0.025) and negative. This indicates that – conditional on initial weight and initial relationship status – loosing body weight increases the likelihood of being involved in a sexual relationship. The point estimate corresponds to an effect of substantial size. At its maximum value ($\hat{\beta}_{\Delta BMI_{1\text{-}10}} \cdot \phi(0)$) the corresponding marginal effect is as high as -0.077. That is one BMI unit reduction in body weight increases the probability of having a sexual partner by 7.7 percentage points. The mean marginal effect in the estimation sample is still 4.1 percentage points.

The estimated error correlation is 0.536 and is statistically significant. From a purely technical perspective, this does not take one by surprise. Since the bivariate descriptive analysis yields a very weak correlation of $BMI_{1\text{-}10}$ and $sexpartner_{11\text{-}22}$ while the control function approach yields a strong negative effect, something needs to balance the latter for consistency of both results. From a non-technical perspective, it conflicts with our earlier reasoning that self-confidence is a major source of unobserved heterogeneity. It rather argues in favor of the desire for physical pleasures driving the correlation. In other words, those who have a great desire for such pleasures are more

Table 4: **Frequency of Sexual Intercourse (estimated coefficients)**

	Males		**Females**		**All**	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexfrequency_{11\text{-}22}$)						
$\Delta\, BMI_{1\text{-}10}$	−0.033	0.090	0.059	0.198	−0.057	0.083
age	−0.036**	0.018	−0.011	0.022	−0.025*	0.013
female	–	–	–	–	−0.503**	0.212
$together_0$	0.677**	0.276	1.458**	0.501	1.065**	0.221
BMI_0	−0.050*	0.026	−0.018	0.034	−0.045**	0.021
control function (dependent variable: $\Delta BMI_{1\text{-}10}$)						
incentive $150_{1\text{-}4}$	−0.817**	0.408	−0.930*	0.544	−0.781**	0.326
incentive $300_{1\text{-}4}$	−0.987**	0.412	−1.256**	0.483	−1.083**	0.322
incentive $250_{5\text{-}10}$	−2.680**	0.421	−1.264**	0.518	−2.262**	0.322
incentive $500_{5\text{-}10}$	−2.077**	0.405	−1.777**	0.528	−1.903**	0.326
age	0.004	0.021	−0.006	0.023	0.001	0.016
female	–	–	–	–	0.075	0.271
$together_0$	−0.491	0.381	0.256	0.421	−0.169	0.290
BMI_0	−0.083**	0.028	0.012	0.029	−0.047**	0.021
constant	3.607**	1.639	−0.141	1.644	2.070*	1.194
ancillary parameters						
threshold 1	−4.364**	1.420	−0.751	1.623	−3.212**	1.022
threshold 2	−3.362**	1.388	−0.195	1.607	−2.394**	1.012
σ (control function error S.D.)	2.654**	0.114	2.257**	0.135	2.556**	0.089
ρ (error correlation)	0.266	0.254	−0.431	0.434	0.173	0.229
# of observations (over all)	271		141		412	
# of observations (main equation)	99		53		152	
log likelihood	−727.5		−357.1		−1098.7	
instrument relevance (p-value, joint sig. instruments)	0.000		0.000		0.000	
sample split (p-value, LR-test)	–		–		0.005	

Notes: ** significant at 5%; * significant at 10%; + significant at 15%.

likely to have sex but are less likely to reduce overeating. In any case, the estimate for ρ indicates that the endogeneity of $\Delta\, BMI_{1\text{-}10}$ is an issue worth to be addressed in the estimation procedure. Interpreting the estimated coefficient in terms of a causal effect critically relies on appropriate instruments that only enter the control function and have substantial explanatory power. Table 3 indicates that the indicators for the experimental groups are indeed strong predictors for the endogenous regressor weight change. The p-value for the test on joint significant is smaller than $5 \cdot 10^{-4}$ and each indicator is individually significant in statistical terms. That is, financial incentives do have a strong effect on success in weight loss, as established elsewhere in the literature (Volpp et al., 2008; John et al., 2011; Augurzky et al., 2012; Cawley and Price, 2013; Augurzky et al., 2014), and there is no reason for being concerned about weak instruments.[17]

In order to dig deeper into the interdependence of body weight an sexual activity we re-estimated the model with an indicator for living together with a partner ($together_0$) as alternative dependent variable, see Appendix Tables 11 and 12. There, we find virtually no effect of a change in body weight. In other words it is not the relationship status per se but its sexual nature that is significantly affected by loosing body weight. In the light of this result one would expect to find also an effect of a change in body weight on the frequency of sexual intercourse. Yet, Table 4 indicates that this does not apply. The point estimate is virtually zero and is accompanied by a

[17]In terms of the corresponding linear model the relevant F-statistic is 17.812 for males.

large standard error. This raises some concerns with respect to our earlier result of a significant effect on $sexpartner_{11\text{-}22}$.

Turning to the results for females, the estimated effect of $\Delta\, BMI_{1\text{-}10}$ on $sexpartner_{11\text{-}22}$ is statistically insignificant. Though the point estimate bears the same sign as its counterparts for males, it is very small and is accompanied by a rather large standard error. One cannot rule out that the effect of body weight on sexual activity is of qualitatively different nature for females as compared to males. Yet, a more trivial explanation for the heterogeneity in results across genders is the small size of the female sample. It includes only 53 individuals for which information on sexual activity is available and, hence, provides a rather weak basis for establishing a causal relationship. Hence it does not take one by surprise that for females significant effects of $\Delta\, BMI_{1\text{-}10}$ are also neither found on $sexfrequency_{11\text{-}22}$ nor on $together_{22}$. For females, the estimate for ρ exhibits the opposite sign but is statistically insignificant, raising further doubts with respect to the reliability of the results found for women.

In order to base the econometric analysis on a larger sample, one may think of pooling males and females. Re-estimating the model using the pooled model yields results which are very close and qualitatively equivalent to what is found for males, which dominate the pooled sample in numbers. However, likelihood ratio tests (p-values: 0.069, 0.005) argue against the hypothesis that the dependent variables are determined by models that are uniform across gender.

5 Model Extensions and Robustness Checks

Having discussed the results for the basic model, we now turn to two additional specifications that address two potential shortcomings of the models discussed above. In Subsection 5.1 we discuss potential invalidity of some of the instruments used and propose alternative specifications, which use fewer instruments for which validity is no reason for concern. In Subsection 5.2 – in addition to what is discussed in Subsection 5.1 – we discuss potential selection bias and propose a model variant that corrects for it.

5.1 Analysis Conditional on Success in Weight-Loss Phase

Though the parametric control function model is non-linear, non-linearity is not sufficient for identification which still rests on valid exclusion restrictions. In the above section, we argued that group membership is purely random and exerts effects on sex life only through the change in body weight. While – by experimental design – randomness applies to group membership in the weight-loss phase, one may however put randomness into question with respect to the group membership in the weight-maintenance phase that is for the indicators *incentive* $250_{5\text{-}10}$ and *incentive* $500_{5\text{-}10}$. This is due to the experimental design that conditions assignment to the intervention groups in the weight-maintenance on success in the preceding phase. In other words, one may argue that the effect of unobserved confounding factors is not be completely eliminated by using *incentive* $150_{1\text{-}4}$, *incentive* $300_{1\text{-}4}$, *incentive* $250_{5\text{-}10}$, and *incentive* $500_{5\text{-}10}$ as instruments, since the latter two are potentially affected by these factors through being successful in loosing body weight during the months one to four.

One obvious approach to deal with this issue is to use only *incentive* $150_{1\text{-}4}$ and *incentive* $300_{1\text{-}4}$ as instruments for $\Delta\, BMI_{1\text{-}10}$. However, as compared to *incentive* $250_{5\text{-}10}$ and *incentive* $500_{5\text{-}10}$, group membership in the weight-loss phase has less explanatory power for the endogenous regressor. That is, group membership in the weight-reduction phase is just a weak instrument for weight loss over the entire intervention period of the experiment. This can easily be explained by long-term effects of financial incentives – if existent – being much smaller than short-term effects (Augurzky et al., 2014). In addition, and even more important, a significant reduced form effect of *incentive* $150_{1\text{-}4}$ and *incentive* $300_{1\text{-}4}$ is not found in the data, neither on $sexpart_{11\text{-}22}$ nor on $sexfrequency_{11\text{-}22}$. In other words identification – even in the basic model – critically rests on *incentive* $250_{5\text{-}10}$, and *incentive* $500_{5\text{-}10}$ being used as instruments.

For this reason we take a different approach to tackling the potential endogeneity of the instruments by conditioning the analysis on success in the weight-reduction phase, i.e. by conditioning on eligibility for the second randomization. We implement this approach in two different ways. The first is (i) confining the analysis to those individuals who did successfully loose weight in the weight-loss phase and, hence, are eligible for the second randomization. Within this sub-sample group membership from month 5 to month 10 is purely random and, in turn, *incentive* $250_{5\text{-}10}$ and *incentive* $500_{5\text{-}10}$ are purely exogenous with respect to weight change over the weight maintenance phase ($\Delta\, BMI_{5\text{-}10}$). This does not hold with respect to weight change over the entire intervention period ($\Delta\, BMI_{1\text{-}10}$). For this reason, in this alternative model that only considers individuals who were successful in the first intervention period $\Delta\, BMI_{5\text{-}10}$ serves as key regressor and *incentive* $250_{5\text{-}10}$ and *incentive* $500_{5\text{-}10}$ as instruments for it. In this model *incentive* $150_{1\text{-}4}$ and *incentive* $300_{1\text{-}4}$ are no valid instruments. One may think of including them as further control variables to the model. Yet – due to randomization – in the considered sub-sample the weight-maintenance incentives are orthogonal to the weight-loss incentives and controlling for possible long-run effects of exposition to the latter is not essential for identification. Hence, for the sake of a parsimoniously specified model, we exclude *incentive* $150_{1\text{-}4}$ and *incentive* $300_{1\text{-}4}$ from the regres-

Table 5: **Sexual Relationship, cond. on success in weight-loss phase (est. coefficients)**

	Males		Females		All	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexpartner_{11\text{-}22}$)						
$\Delta\, BMI_{5\text{-}10}$	-0.403^{**}	0.087	0.422^{**}	0.118	-0.368^{**}	0.154
age	-0.003	0.016	0.023^{+}	0.015	-0.015	0.014
female	–	–	–	–	-0.325	0.310
$together_4$	0.738^{*}	0.384	-0.005	0.660	1.133^{**}	0.474
BMI_4	-0.034	0.029	-0.045^{*}	0.026	-0.045	0.033
constant	1.549	1.383	0.389	1.120	2.369^{*}	1.372
control function (dependent variable: $\Delta\, BMI_{5\text{-}10}$)						
$incentive\,250_{5\text{-}10}$	-1.409^{**}	0.396	-0.191	0.447	-1.040^{**}	0.325
$incentive\,500_{5\text{-}10}$	-1.015^{**}	0.369	-0.423	0.611	-0.719^{**}	0.326
age	0.004	0.020	-0.049^{*}	0.027	-0.014	0.016
female	–	–	–	–	0.117	0.291
$together_4$	-0.103	0.378	0.799^{+}	0.518	0.266	0.310
BMI_4	-0.031	0.029	0.079^{**}	0.036	0.012	0.023
constant	2.095	1.501	-0.288	1.811	1.003	1.177
ancillary parameters						
σ (control function error S.D.)	2.116^{**}	0.112	2.085^{**}	0.164	2.150^{**}	0.094
ρ (error correlation)	0.851^{**}	0.142	-0.976^{**}	0.080	0.687^{**}	0.347
# of observations (over all)	179		81		260	
# of observations (main equation)	65		32		97	
log likelihood	-410.1		-188.0		-605.7	
instrument relevance (p-value, joint sig. instruments)	0.001		0.773		0.005	
sample split (p-value, LR-test)	–		–		0.170	

Notes: ** significant at 5%; * significant at 10%; $^{+}$ significant at 15%. All model equations estimated using only individuals who successfully lost body weight during month one to four.

sion model.[18] Moreover, as in this variant of the model identification rests exclusively on weight variation over the maintenance phase, we condition on the values of the control variables (initial *BMI*, relationship status) four months after experiment start.

Confining the analysis to individuals who are eligible to the second randomization reduces the size of the estimation sample considerably.[19] The second model variant addresses this shortcoming by (ii) estimating the model described above using the entire sample, i.e. including those individuals who did not qualify for the second randomization. Yet, estimation is still conditional on the weight-outcome of the weight-loss phase since a further binary control variable $success_4$ is included, indicating eligibility for the second randomization four month after rehab discharge. The reasoning behind this specification is that conditional on failure or success the instruments $incentive\,250_{5\text{-}10}$ and $incentive\,500_{5\text{-}10}$ are exogenous. However $success_4$ is certainly a 'bad control' as it itself represents an outcome variable closely related to the endogenous regressor $\Delta\, BMI_{5\text{-}10}$. We address this by augmenting the model by a further control function that explains $success_4$ and uses $incentive\,150_{1\text{-}4}$ and $incentive\,300_{1\text{-}4}$ as instruments. As discussed in Augurzky et al. (2012), the weight-loss incentives have strong explanatory power for success in the weight-loss phase of the experiment.

[18] Letting $incentive\,150_{1\text{-}4}$ and $incentive\,300_{1\text{-}4}$ enter the regression model as further controls has little effect on the estimate for the key coefficient.

[19] The value for N is reduced to 260 as compared to 412 for the basic model (pooled sample); see Tables 3 and 5.

Table 6: **Frequency of Intercourse, cond. on success in weight-loss phase (est. coefficients)**

	Males		Females		All	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexfrequency_{11\text{-}22}$)						
$\Delta\, BMI_{5\text{-}10}$	-0.275^{*}	0.146	0.462^{**}	0.091	-0.268^{+}	0.186
age	-0.023	0.019	0.022	0.016	-0.026^{*}	0.014
female	–	–	–	–	-0.115	0.249
$together_4$	0.519^{*}	0.313	-0.133	0.967	0.945^{**}	0.348
BMI_4	-0.045^{+}	0.030	-0.047	0.039	-0.049^{+}	0.031
control function (dependent variable: $\Delta\, BMI_{5\text{-}10}$)						
$incentive\,250_{5\text{-}10}$	-1.280^{**}	0.440	0.028	0.189	-0.980^{**}	0.346
$incentive\,500_{5\text{-}10}$	-1.170^{**}	0.358	-0.171	0.758	-0.833^{**}	0.310
age	0.003	0.020	-0.050^{*}	0.027	-0.014	0.016
female	–	–	–	–	0.108	0.291
$together_4$	-0.106	0.379	0.765^{+}	0.516	0.262	0.311
BMI_4	-0.033	0.029	0.078^{**}	0.036	0.011	0.023
constant	2.236^{+}	1.502	-0.298	1.818	1.056	1.176
ancillary parameters						
threshold 1	-3.245^{*}	1.730	-0.498	1.651	-3.200^{**}	1.436
threshold 2	-2.528^{+}	1.546	-0.435	1.444	-2.558^{**}	1.273
σ (control function error S.D.)	2.120^{**}	0.112	2.090^{**}	0.164	2.151^{**}	0.094
ρ (error correlation)	0.750^{**}	0.233	-0.993^{**}	0.061	0.627^{*}	0.368
# of observations (over all)	179		81		260	
# of observations (main equation)	63		32		95	
log likelihood	-437.9		-196.6		-645.6	
instrument relevance (p-value, joint sig. instruments)	0.002		0.939		0.006	
sample split (p-value, *LR*-test)	–		–		0.015	

Notes: ** significant at 5%; * significant at 10%; $^{+}$ significant at 15%. All model equations estimated using only individuals who successfully lost body weight during month one to four.

Tables 5 and 6 display estimation results for the variant of the model that confines the analysis to those, who successfully lost weight over month one to month four. As before, besides estimating a pooled model, we estimate the model stratified by gender. Here, the females' regression clearly does not yield reliable results for the causal effect of body weight on women's sex life. The reason for this is the very low explanatory power the instruments have for $\Delta\, BMI_{5\text{-}10}$. The p-value for the test on joint significant is as high as 0.773 indicating that the incentive indicators are weak instruments in the females' sub-sample. Thus, the puzzling positive and – in the regression explaining $sexpartner_{11\text{-}22}$ – significant coefficient of $\Delta\, BMI_{5\text{-}10}$ represents an artifact of weak instruments.

This argument does not apply to the male's sub-sample and the pooled sample, see Tables 5 and 6. There, the tests on the joint significance of $incentive\,250_{5\text{-}10}$ and $incentive\,500_{5\text{-}10}$ yield much smaller p-values (0.001 and 0.002). The coefficients attached to $\Delta\, BMI_{5\text{-}10}$ – in qualitative terms – confirm what is found in the specification that uses weight change over the entire intervention period as explanatory variable. That is weight-loss significantly increases the probability for being involved in a sexual relationship for males and in the pooled sample. Yet, the coefficients are much larger in magnitude as compared to Table 3 and 4. Marginal effects on the probability of $sexpartner_{11\text{-}22}$ taking the value of one are more than two times larger, reaching the value of -0.161 at its maximum. In other words, loosing one BMI unit in bodyweight makes an sexual

Table 7: **Sexual Relationship, control for success in weight-loss phase (est. coef.)**

	Males		Females		All	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexpartner_{11\text{-}22}$)						
$\Delta\, BMI_{5\text{-}10}$	-0.425^{**}	0.166	-0.004	0.107	-0.386^{**}	0.150
age	-0.007	0.016	-0.011	0.018	-0.020^{*}	0.012
female	–	–	–	–	-0.690^{**}	0.289
$together_4$	0.579^{**}	0.289	1.561^{**}	0.483	1.233^{**}	0.484
BMI_4	-0.039	0.029	-0.000	0.032	-0.027	0.023
$success_4$	0.549	0.951	-0.564^{*}	0.316	-0.612	0.627
constant	1.732	1.240	-0.113	1.423	2.391^{**}	0.957
control function (dependent variable: $\Delta\, BMI_{5\text{-}10}$)						
$incentive\ 250_{5\text{-}10}$	-1.382^{**}	0.396	-0.681	0.510	-1.018^{**}	0.295
$incentive\ 500_{5\text{-}10}$	-0.962^{**}	0.372	-0.689	0.541	-0.731^{**}	0.300
age	-0.012	0.020	-0.045^{**}	0.021	-0.028^{**}	0.013
female	–	–	–	–	-0.288	0.222
$together_4$	-0.077	0.311	0.779^{**}	0.375	0.276	0.237
BMI_4	-0.002	0.023	0.032	0.027	0.009	0.017
$success_4$	-0.924	1.022	-0.443	0.453	-1.086	0.816
constant	2.281^{+}	1.444	1.293	1.519	2.384^{**}	1.039
control function (dependent variable: $success_4$)						
$incentive\ 150_{1\text{-}4}$	0.599^{**}	0.165	0.369^{+}	0.252	0.559^{**}	0.145
$incentive\ 300_{1\text{-}4}$	0.562^{**}	0.166	0.833^{**}	0.234	0.650^{**}	0.146
age	0.000	0.009	-0.015	0.012	-0.006	0.007
female	–	–	–	–	-0.179^{+}	0.122
$together_0$	0.373^{**}	0.165	0.253	0.214	0.260^{**}	0.130
BMI_0	0.013	0.013	-0.005	0.016	0.006	0.010
constant	-0.840	0.725	0.467	0.834	-0.245	0.532
ancillary parameters						
σ (control function error S.D.)	1.986^{**}	0.141	2.066^{**}	0.124	2.096^{**}	0.159
ρ^{sex}_{bmi}	0.641^{*}	0.379	-0.243	–	0.707^{**}	0.311
$\rho^{sex}_{success}$	-0.413	0.540	0.772^{**}	0.037	0.498	0.365
$\rho^{bmi}_{success}$	0.435^{*}	0.258	0.429	–	0.486^{**}	0.205
# of observations (over all)	347		172		519	
# of observations (main equation)	103		53		156	
log likelihood	-808.3		-420.8		-1246.2	
instrument relevance (p-value, joint sig. instruments)	0.002		0.307		0.002	
sample split (p-value, LR-test)	–		–		0.017	

Notes: ** significant at 5%; * significant at 10%; $^{+}$ significant at 15%.

relationship substantially more likely. Estimating the model on basis of the pooled sample yields a similar result.

Unlike the results discussed in section 4, a significant – at the ten percent level – and negative effect of $\Delta\, BMI_{5\text{-}10}$ is also found for $sexfrequency_{11\text{-}22}$, see Table 6. That is, estimating the model conditional on success in the weight-loss phase yields not only the result that loosing body weight makes a sexual relationship more likely but also that having actually sex becomes more frequent if obese individuals become less overweight. One may explain this finding, which deviates from the results discussed in Section 4, by relying on more credible exclusion restrictions. An alternative explanation could be that adjusting sex life habits (in an existing partnership) takes some time and reduced body weight comes only in effect if it is maintained for some time. Due to the ordinal nature of $sexfrequency_{11\text{-}22}$ the coefficient is not easily interpreted in qualitative terms. Yet, one may interpret the coefficient such that if the odds for having sex at least as frequent as indicated by the kth category of $sexfrequency_{11\text{-}22}$ are 50 percent, a one BMI unit reduction in body weight

Table 8: **Frequency of Intercourse, control for success in weight-loss phase (est. coef.)**

	Males		Females		All	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexfrequency_{11\text{-}22}$)						
$\Delta\, BMI_{5\text{-}10}$	-0.296^{*}	0.175	0.392^{**}	0.077	-0.268^{+}	0.183
age	-0.031^{**}	0.015	0.020	0.018	-0.031^{**}	0.012
female	–	–	–	–	-0.533^{**}	0.211
$together_4$	0.416^{+}	0.262	0.204	1.156	0.979^{**}	0.308
BMI_4	-0.040^{+}	0.025	-0.016	0.021	-0.031^{+}	0.021
$success_4$	0.084	0.794	0.938^{+}	0.615	-0.829^{+}	0.531
control function (dependent variable: $\Delta\, BMI_{5\text{-}10}$)						
$incentive\, 250_{5\text{-}10}$	-1.322^{**}	0.376	-0.227	0.441	-0.973^{**}	0.308
$incentive\, 500_{5\text{-}10}$	-1.075^{**}	0.328	-0.423	0.546	-0.822^{**}	0.288
age	-0.013	0.016	-0.059^{**}	0.024	-0.028^{**}	0.013
female	–	–	–	–	-0.294	0.222
$together_4$	-0.075	0.286	0.891^{*}	0.461	0.277	0.236
BMI_4	-0.004	0.022	0.025	0.031	0.009	0.017
$success_4$	-0.772	0.883	-2.566^{**}	0.916	-1.097	0.788
constant	2.294^{*}	1.233	3.250^{*}	1.721	2.408^{**}	1.034
control function (dependent variable: $success_4$)						
$incentive\, 150_{1\text{-}4}$	0.661^{**}	0.167	0.390^{+}	0.246	0.553^{**}	0.143
$incentive\, 300_{1\text{-}4}$	0.555^{**}	0.166	0.571^{**}	0.243	0.647^{**}	0.144
age	0.000	0.009	-0.020^{+}	0.013	-0.006	0.007
female	–	–	–	–	-0.177^{+}	0.122
$together_0$	0.324^{**}	0.162	0.161	0.218	0.264^{**}	0.129
BMI_0	0.013	0.013	0.001	0.016	0.007	0.010
constant	-0.823	0.703	0.614	0.824	-0.255	0.531
ancillary parameters						
threshold 1	-3.717^{**}	1.378	1.035	1.236	-3.475^{**}	0.976
threshold 2	-2.956^{**}	1.271	1.241	0.979	-2.829^{**}	0.880
σ (control function error S.D.)	1.977^{**}	0.146	2.521^{**}	0.240	2.101^{**}	0.156
ρ^{sex}_{bmi}	0.558^{+}	0.356	-0.942^{**}	0.241	0.607^{*}	0.357
$\rho^{sex}_{success}$	-0.286	0.479	-0.613	0.553	0.519^{+}	0.334
$\rho^{bmi}_{success}$	0.384^{+}	0.246	0.826^{**}	0.113	0.493^{**}	0.196
# of observations (over all)	347		172		519	
# of observations (main equation)	99		53		152	
log likelihood	-851.6		-436.3		-1310.6	
instrument relevance (p-value, joint sig. instruments)	0.001		0.734		0.002	
sample split (p-value, LR-test)	–		–		0.000	

Notes: ** significant at 5%; * significant at 10%; + significant at 15%.

increases this probability by 11 percentage points. As before, the results for the pooled sample largely mirror what is found for males.

Turning to the results for the model variant that uses the full sample for estimation but includes $success_4$ as control and adds a second control function, see Tables 7 and 8, they largely mirror what is found for the conditional model discussed above. Results for females still seem not to be reliable because of relatively weak instruments. The key point estimate, as far as the model explaining $sexpartner_{11\text{-}22}$ is concerned, indeed differs much from the corresponding estimate result reported in Table 5, shedding further doubts on the results found for women. This does not apply to the males' and pooled sample. There the estimated coefficients of $\Delta\, BMI_{5\text{-}10}$ are very similar to their counterparts from the model that only considers successful individuals. This also applies to the estimated standard errors and, in turn, to the levels of statistical significance. This corresponds to both variants of the model relying on variation in $\Delta\, BMI_{5\text{-}10}$ within the group of successful weight losers for identifying the effect of weight change on sexual activity.

It nevertheless provides more credence in the robustness of the results to changes in the model specification.

5.2 Selection Correction

One major concern about the present analysis is, as compared to the initial study population, the small size of the actual estimation sample. In other words, the experiment suffers from severe sample attrition, which may not be exogenous and, in turn, may be a source of bias. Besides randomly removing all questions concerning sexual behavior from roughly one-half of the questionnaires – which does not challenge consistency – two distinct processes are responsible for the small number of individuals for whom information about sex life is available. As one can easily imagine, questions concerning the respondents' sexual behavior are delicate and, for this reason, are subject to item non-response. Yet, in our data the rate of denied information is smaller than 0.1, which is remarkably low compared to survey studies that ask for information on sex life (Fenton et al., 2001). This rate applies to those, who have completed the experiment and provided information on body weight at its final stage. Yet – more importantly – roughly 55 percent of the participants dropped out at some point in time and denied providing further information.[20] In most cases dropping out took place without explicit notice to experimenters by not showing-up at the weigh-in and not returning the questionnaire, even after receiving reminder letters and reminder phone calls. Taken all sources of missing information together, information on sex life is available for just 22.5 percent of the original study population.

While item non response is not easily addressed in the econometric analysis, the experiment generated information that can be used to address drop-out. Since the show-up fee for attending the weigh-ins is flat and does not account for the actual costs of providing the requested information, the actual net-cost of experiment continuation varies substantially across individuals. A major determinant of costs differentials is group membership as for – successful – members of the incentive groups, dropping out means foregoing financial rewards. Yet, this information is already exhausted for explaining changes in body weight and cannot be used as an instrument for compliance. However, another determinant is travel cost. Though no precise measure for this cost is available – which is highly subjective und inherently unobservable – the data include an indicator for the place of weigh-in is located within the same zip-code area as the participant's place of residence. Since the pharmacy to be visited for the weigh-ins was assigned by the experimenter, this variable ($\textit{pharmacy nearby}_{1\text{-}22}$) represents an exogenous source of variation in travel

[20] With respect to dropping out, body weight is the key piece of information. As providing information about body weight requires attending a weigh-in it is more costly than filling-in a questionnaire, which is sufficient for providing information concerning other variables.

Table 9: **Sexual Relationship, selection correction (estimated coefficients)**

	Males		Females		All	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexpartner_{11\text{-}22}$)						
$\Delta\, BMI_{5\text{-}10}$	-0.359^{**}	0.164	–	–	-0.322^{*}	0.178
age	0.011	0.025	–	–	-0.000	0.012
female	–	–	–	–	-0.059	0.225
$together_4$	0.260	0.299	–	–	0.482^{**}	0.235
BMI_4	-0.062^{*}	0.037	–	–	-0.058^{*}	0.034
constant	1.258	1.802	–	–	1.436	1.201
control function (dependent variable: $\Delta\, BMI_{5\text{-}10}$)						
$incentive\ 250_{5\text{-}10}$	-1.399^{**}	0.500	–	–	-1.090^{**}	0.389
$incentive\ 500_{5\text{-}10}$	-1.068^{**}	0.479	–	–	-0.750^{**}	0.365
age	0.007	0.028	–	–	-0.013	0.018
female	–	–	–	–	0.112	0.334
$together_4$	-0.111	0.418	–	–	0.289	0.323
BMI_4	-0.032	0.030	–	–	0.012	0.021
constant	2.038	2.013	–	–	1.004	1.311
selection equation (dependent variable: $sexinfo_{22}$)						
$pharmacy\ nearby_{1\text{-}22}$	0.880^{**}	0.205	–	–	0.858^{**}	0.166
$incentive\ 250_{5\text{-}10}$	-0.251	0.249	–	–	-0.010	0.205
$incentive\ 500_{5\text{-}10}$	0.141	0.252	–	–	0.162	0.196
age	0.020	0.014	–	–	0.014	0.011
female	–	–	–	–	0.110	0.177
$together_4$	-0.384^{+}	0.262	–	–	-0.305^{+}	0.200
BMI_4	-0.061^{**}	0.027	–	–	-0.050^{**}	0.019
constant	0.486	1.261	–	–	0.279	0.844
ancillary parameters						
σ (control function error S.D.)	2.133^{**}	0.099	–	–	2.167^{**}	0.072
ρ^{sex}_{bmi}	0.689^{**}	0.347	–	–	0.555	0.414
ρ^{sex}_{info}	0.691^{*}	0.389	–	–	0.809^{**}	0.302
ρ^{bmi}_{info}	-0.047	0.144	–	–	-0.039	0.106
# of observations (over all)	212		–		307	
# of observations (main equation)	65		–		97	
log likelihood	-515.8		–		-763.5	
exclusion restriction (p-value, selection equation)	0.000		–		0.000	
sample split (p-value, LR-test)	–		–		0.390	

Notes: ** significant at 5%; * significant at 10%; $^{+}$ significant at 15%. All model equations estimated using only individuals who successfully lost body weight during month one to four.

cost and can be used as instrument for providing information on sex life at the final stage of the experiment. In oder words, the underlying intuition for using $pharmacy\ nearby_{1\text{-}22}$ as instrument is that being sent to a nearby pharmacy is positively correlated with program continuation because of little time- and transportation costs, but it should in no way be related directly to sexual behavior.

In terms of the econometric model we augment the first variant of the model discussed in section 5.1 (only successful participants included) by a selection equation that explains whether or not information on individuals i's sex life is available in the data ($sexinfo_{22}$)[21] and that includes $pharmacy\ nearby_{1\text{-}22}$ as additional explanatory variable.[22] Following our previous modelling strategy, we assume joint normality with the main equation and the control function and estimate all

[21] Item-non-response slightly varies between the two dependent variables $sexpartner_{11\text{-}22}$ and $sexfrequency_{11\text{-}22}$. Hence, the dependent variable of the selection equation $sexinfo_{22}$ is differently defined for the two variants of the model.

[22] One may also augment the model that includes $success_4$ as control by a third control function explaining $sexinfo_{22}$. This would however require simulated ML estimation, involving a substantial computational burden. Hence, given that the two variants of the model discussed in section 5.1 yield very similar results, we focus on the first variant when addressing the problem of possible selection bias.

Table 10: **Frequency of Intercourse, selection correction (estimated coefficients)**

	Males		Females		All	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexfrequency_{11\text{-}22}$)						
$\Delta\, BMI_{5\text{-}10}$	-0.316^{**}	0.131	–	–	-0.331^{**}	0.122
age	-0.014	0.025	–	–	-0.015	0.012
female	–	–	–	–	0.013	0.210
$together_4$	0.356	0.318	–	–	0.563^{**}	0.272
BMI_4	-0.054	0.039	–	–	-0.054^{+}	0.033
control function (dependent variable: $\Delta\, BMI_{5\text{-}10}$)						
$incentive\ 250_{5\text{-}10}$	-1.183^{**}	0.495	–	–	-0.922^{**}	0.379
$incentive\ 500_{5\text{-}10}$	-1.210^{**}	0.473	–	–	-0.878^{**}	0.355
age	0.003	0.028	–	–	-0.014	0.018
female	–	–	–	–	0.105	0.335
$together_4$	-0.110	0.432	–	–	0.260	0.321
BMI_4	-0.034	0.029	–	–	0.011	0.020
constant	2.290	1.948	–	–	1.089	1.279
selection equation (dependent variable: $sexinfo_{22}$)						
$pharmacy\ nearby_{1\text{-}22}$	0.815^{**}	0.220	–	–	0.843^{**}	0.172
$incentive\ 250_{5\text{-}10}$	-0.085	0.280	–	–	0.126	0.209
$incentive\ 500_{5\text{-}10}$	0.213	0.266	–	–	0.125	0.202
age	0.022^{+}	0.014	–	–	0.014	0.010
female	–	–	–	–	0.129	0.181
$together_4$	-0.296	0.278	–	–	-0.229	0.207
BMI_4	-0.063^{**}	0.028	–	–	-0.053^{**}	0.019
constant	0.312	1.334	–	–	0.247	0.855
ancillary parameters						
threshold 1	-2.776	1.952	–	–	-2.371^{*}	1.346
threshold 2	-2.174	1.815	–	–	-1.912^{+}	1.228
σ (control function error S.D.)	2.124^{**}	0.095	–	–	2.154^{**}	0.069
ρ^{sex}_{bmi}	0.805^{**}	0.186	–	–	0.747^{**}	0.246
ρ^{sex}_{info}	0.243	0.371	–	–	0.434^{+}	0.296
ρ^{bmi}_{info}	-0.061	0.149	–	–	-0.045	0.109
# of observations (over all)	212		–		307	
# of observations (main equation)	63		–		95	
log likelihood	-547.2		–		-808.6	
exclusion restriction (p-value, selection equation)	0.000		–		0.000	
sample split (p-value, LR-test)	–		–		0.047	

Notes: ** significant at 5%; * significant at 10%; $^{+}$ significant at 15%. All model equations estimated using only individuals who successfully lost body weight during month one to four.

model parameters jointly by maximum likelihood. Estimation results are displayed in the Tables 9 and 10. No results are reported for the females' sub-sample because of weak instruments, already discussed in section 5.1.

The relevant tests indicate that $pharmacy\ nearby_{1\text{-}22}$ has substantial explanatory power for $sexinfo_{22}$, i.e. identification rests on a strong exclusion restriction. This is in line with missing information being predominantly due to drop-out from the experiment while item-non-response – which should not be correlated with $pharmacy\ nearby_{1\text{-}22}$ – plays just a marginal role. The point estimates for the error correlation ρ^{sex}_{info} are positive, pointing to unobserved factors – such as personal traits – that make individuals sexually more active and, at the same time, more willing to reveal information about their sex lives.

The selection correction model confirms the previous results, and hence provides some confidence in the estimation results not representing an artifact of self-selection. In all variants of the model, the coefficients attached to $\Delta\, BMI_{5\text{-}10}$ bear the same sign and are of similar magnitude as their counterparts in Table 5 and Table 6. The largest deviation from the results without selection correction is found for the model explaining *sexpartner*$_{11\text{-}22}$ only considering males. There, the coefficient gets somewhat smaller in absolute terms while the estimated standard error gets almost twice as large if the selection equation is added to the model. Yet, the relevant p-value is still as low as 0.028. The key result that weight loss exerts a significant and positive effect of substantial magnitude on both the probability of sexual relationship and the frequency of intercourse is hence not challenged by correction for endogenous sample selection. This also applies to a slightly different variant of the model that uses the entire sample for estimating the selection equation and not just those individuals who qualify for the second randomization.

6 Discussion and Conclusions

This paper analyzed whether weight reduction in adult obese individuals exerts an effect of their sex lives, namely whether or not they live in a sexual partnership and how frequently they have sex. Based on data generated by a randomized field experiment, where randomization provides an exogenous source of variation in body weight that is exploited for identification, we find that obese males are substantially more likely to be involved in a sexual relationship if they get less overweight. This effect is of substantial magnitude reaching, depending on the model specification, 8 to 17 percentage points for the most effected individual. The results are not as clear for the frequency of sexual intercourse. Yet, in males who have already lost weight, estimation results indicate that further weight reduction – or at least weight maintenance – results in having sex more frequently. For males the key results are robust to several variations to the specification, such as being more restrictive in choosing valid instruments, choosing a different observation period for the key explanatory variable, estimating a linear probability rather than a probit model, and to correcting for experiment-dropout via augmenting the model by a selection equation.

In contrast, for females the analysis does not yield any significant and reliable effect. This can be explained by the small number of women in our data that seriously hampers the empirical analysis. Yet, gender differentials in what determines sex life might provide another explanation. According to Baumeister et al. (2001) there is ample empirical evidence for men – as compared to women – having more frequent and more intense sexual desires. The strength of sexual motivation, also referred to as sex drive, is for instance reflected in the desired number of partners and the desired frequency of intercourse, which are closely related to the outcome variables of the present study. The stronger male sex drive may render detecting a causal effect of weight loss easier for men than for women. Based on an extensive literature survey, Petersen and Hyde

(2010) state only small gender differences in many sexual behaviours. Yet, casual sex and attitudes toward casual sex are among the exceptions to this general finding. Regarding these two dimensions men report a more active sexual behavior or express more permissive attitudes towards them than women do. This diverging predisposition could be another explanation for the significant effects found for men but not for women, concerning the probability for being involved in a sexual relationship and the frequency of sexual intercourse

Since for many individuals a fulfilling sex life is an important facet of general life satisfaction and happiness, our key result may provide additional motivation for obese males to reduce overweight, similar to tobacco education where preventing impairments in sexual life is an important argument for smoking cessation (Linnebur, 2006). Moreover, it provides further evidence for substantial social costs of obesity that are not necessarily linked to pathological health problems. This raises the question about the channels through which the established effects operates, which cannot be decided on basis of the data used in this study. One possibility is recovery from sexual dysfunction on which the medical literature has focussed. Yet, given strong effects of a moderate weight reduction found in the data, other channels are likely to also play a role. Greater self-confidence when initiating sexual contact, improved attractiveness to potential sexual partners, feeling more comfortable with its own body, and more desire for sex may act as such channels. One limitation of the present analysis is that it does not allow for disentangling the effect of a reduced body weight from the effect of the process of weight reduction. The strong effects found may therefore rather be attributed to being successful in meeting a major individual challenge than to weight-loss itself. One possible route to address this question were to evaluate the effects of bariatric surgeries on sexual activity.

While the existing non-medical literature had a strong focus of the effect of overweight on young individuals' sex lives, our result explicitly refers to adult obese individuals. Thus can be interpreted in terms of another desirable consequence of weight reduction. In fact the argument of overweight having the desirable side effect of counteracting premature initiation to sex, put forward elsewhere in the literature, does not apply given the age group considered in the present analysis. Our results rather provides further evidence for obesity imposing restrictions on private lives, but also for even moderate weight reduction mitigating these limitations.

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A Appendix

A.1 Results for 'living with a partner' ($together_{22}$) as dependent variable

Table 11: **Living with a Partner (estimated coefficients)**

	Males		Females		All	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $together_{22}$)						
$\Delta\, BMI_{1\text{-}10}$	0.038	0.108	0.159	0.195	0.086	0.092
age	0.018	0.018	0.000	0.023	0.011	0.014
female	–	–	–	–	−0.212	0.237
$together_0$	3.321**	0.356	3.109**	0.517	3.209**	0.288
BMI_0	0.026	0.028	0.036	0.034	0.030	0.021
constant	−3.481**	1.590	−2.830+	1.928	−3.091**	1.187
control function (dependent variable: $\Delta\, BMI_{1\text{-}10}$)						
$incentive\ 150_{1\text{-}4}$	−0.803*	0.413	−0.715	0.519	−0.812**	0.324
$incentive\ 300_{1\text{-}4}$	−1.008**	0.418	−1.184**	0.496	−1.110**	0.321
$incentive\ 250_{5\text{-}10}$	−2.702**	0.423	−1.397**	0.495	−2.248**	0.325
$incentive\ 500_{5\text{-}10}$	−2.036**	0.409	−1.771**	0.531	−1.886**	0.326
age	0.004	0.021	−0.007	0.023	0.001	0.016
female	–	–	–	–	0.079	0.271
$together_0$	−0.490	0.381	0.277	0.420	−0.170	0.290
BMI_0	−0.082**	0.028	0.012	0.029	−0.047**	0.021
constant	3.579**	1.641	−0.151	1.643	2.081*	1.194
ancillary parameters						
σ (control function error S.D.)	2.654**	0.114	2.255**	0.134	2.556**	0.089
ρ (error correlation)	−0.063	0.333	−0.136	0.491	−0.146	0.266
# of observations (over all)	271		141		412	
# of observations (main equation)	208		106		314	
log likelihood	−691.2		−341.7		−1041.1	
instrument relevance (p-value, joint sig. instruments)	0.000		0.000		0.000	
sample split (p-value, LR-test)	–		–		0.222	

Notes: * significant at 5%; + significant at 10%.

Table 12: **Living with a Partner, weight change over 22 months (est. coef.)**

	Males		Females		All	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $together_{22}$)						
$\Delta\, BMI_{1\text{-}22}$	0.034	0.191	0.086	0.224	0.133	0.128
age	0.017	0.019	0.000	0.022	0.008	0.014
female	–	–	–	–	−0.229	0.237
$together_0$	3.406**	0.575	3.094**	0.474	3.248**	0.412
BMI_0	0.030	0.037	0.031	0.033	0.036*	0.022
constant	−3.636*	1.882	−2.806+	1.823	−3.253**	1.173
control function (dependent variable: $\Delta\, BMI_{1\text{-}22}$)						
$incentive\ 150_{1\text{-}4}$	−0.660	0.624	−1.307*	0.773	−0.914*	0.477
$incentive\ 300_{1\text{-}4}$	−0.851	0.629	−1.598**	0.761	−1.157**	0.468
$incentive\ 250_{5\text{-}10}$	−1.790**	0.625	−0.545	0.755	−1.275**	0.479
$incentive\ 500_{5\text{-}10}$	−0.918+	0.618	−1.494*	0.806	−1.021**	0.482
age	0.015	0.032	0.009	0.035	0.012	0.024
female	–	–	–	–	0.219	0.399
$together_0$	−0.990*	0.551	0.344	0.635	−0.446	0.425
BMI_0	−0.123**	0.042	−0.001	0.049	−0.080**	0.032
constant	4.976**	2.449	0.388	2.556	3.257*	1.800
ancillary parameters						
σ (control function error S.D.)	3.416**	0.167	2.981**	0.204	3.318**	0.132
ρ (error correlation)	0.106	0.664	−0.031	0.711	−0.246	0.460
# of observations (over all)	209		107		316	
# of observations (main equation)	207		106		313	
log likelihood	−594.3		−295.8		−895.9	
instrument relevance (p-value, joint sig. instruments)	0.006		0.052		0.001	
sample split (p-value, LR-test)	–		–		0.566	

Notes: * significant at 5%; + significant at 10%.

A.2 Results for spec. considering weight change over 22 months ($\Delta BMI_{1\text{-}22}$)

Table 13: **Sexual Relationship, $\Delta BMI_{1\text{-}22}$ (estimated coefficients)**

	Males		Females		All	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexpartner_{11\text{-}22}$)						
$\Delta BMI_{1\text{-}22}$	-0.233^{**}	0.061	-0.039	0.236	-0.207^{*}	0.114
age	0.010	0.016	-0.028	0.025	-0.005	0.015
female	–	–	–	–	-0.576^{**}	0.287
$together_0$	0.798^{+}	0.506	1.642^{*}	0.896	1.362^{**}	0.463
BMI_0	-0.057^{**}	0.024	0.045	0.044	-0.047^{*}	0.024
constant	1.575	1.211	-1.010	1.822	1.798^{+}	1.144
control function (dependent variable: $\Delta BMI_{1\text{-}22}$)						
$incentive\ 150_{1\text{-}4}$	-0.378	0.584	-1.563^{**}	0.723	-0.747	0.519
$incentive\ 300_{1\text{-}4}$	-0.726	0.565	-1.648^{**}	0.730	-1.044^{**}	0.492
$incentive\ 250_{5\text{-}10}$	-1.863^{**}	0.575	-0.435	0.679	-1.417^{**}	0.465
$incentive\ 500_{5\text{-}10}$	-1.051^{*}	0.544	-1.305^{+}	0.824	-1.023^{**}	0.474
age	0.015	0.032	0.010	0.035	0.012	0.024
female	–	–	–	–	0.207	0.399
$together_0$	-0.974^{*}	0.551	0.312	0.635	-0.435	0.425
BMI_0	-0.123^{**}	0.042	-0.002	0.049	-0.079^{**}	0.032
constant	4.860^{**}	2.430	0.433	2.557	3.170^{*}	1.804
ancillary parameters						
σ (control function error S.D.)	3.418^{**}	0.167	2.984^{**}	0.204	3.319^{**}	0.132
ρ (error correlation)	0.793^{**}	0.203	-0.688^{*}	0.370	0.456	0.443
# of observations (over all)	209		107		316	
# of observations (main equation)	103		53		156	
log likelihood	-588.3		-289.0		-889.6	
instrument relevance (p-value, joint sig. instruments)	0.007		0.057		0.001	
sample split (p-value, *LR*-test)	–		–		0.004	

Notes: ** significant at 5%; * significant at 10%; $^{+}$ significant at 15%.

Table 14: **Frequency of Sexual Intercourse, $\Delta BMI_{1\text{-}22}$ (estimated coefficients)**

	Males		Females		All	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexfrequency_{11\text{-}22}$)						
$\Delta BMI_{1\text{-}22}$	-0.037	0.149	0.143	0.121	-0.058	0.134
age	-0.037^{**}	0.019	-0.015	0.017	-0.025^{*}	0.013
female	–	–	–	–	-0.478^{**}	0.216
$together_0$	0.661^{**}	0.332	0.964^{+}	0.617	1.086^{**}	0.228
BMI_0	-0.056^{**}	0.028	0.010	0.027	-0.045^{*}	0.023
control function (dependent variable: $\Delta BMI_{1\text{-}22}$)						
$incentive\ 150_{1\text{-}4}$	-0.708	0.605	-1.794^{**}	0.672	-0.900^{*}	0.500
$incentive\ 300_{1\text{-}4}$	-0.869^{+}	0.595	-1.373^{*}	0.743	-1.136^{**}	0.483
$incentive\ 250_{5\text{-}10}$	-1.737^{**}	0.613	-0.330	0.561	-1.314^{**}	0.474
$incentive\ 500_{5\text{-}10}$	-1.000^{+}	0.610	-0.964	0.789	-1.000^{**}	0.503
age	0.015	0.032	0.011	0.035	0.012	0.024
female	–	–	–	–	0.218	0.400
$together_0$	-0.994^{*}	0.551	0.247	0.638	-0.445	0.425
BMI_0	-0.124^{**}	0.042	-0.007	0.049	-0.079^{**}	0.032
constant	5.069^{**}	2.435	0.494	2.572	3.239^{*}	1.800
ancillary parameters						
threshold 1	-4.680^{**}	1.407	-0.182	1.225	-3.235^{**}	1.069
threshold 2	-3.673^{**}	1.391	0.187	1.246	-2.396^{**}	1.063
σ (control function error S.D.)	3.416^{**}	0.167	3.005^{**}	0.208	3.318^{**}	0.132
ρ (error correlation)	0.201	0.518	-0.880^{**}	0.143	0.040	0.460
# of observations (over all)	209		107		316	
# of observations (main equation)	99		53		152	
log likelihood	-632.5		-304.4		-954.1	
instrument relevance (p-value, joint sig. instruments)	0.006		0.108		0.001	
sample split (p-value, *LR*-test)	–		–		0.001	

Notes: ** significant at 5%; * significant at 10%; $^{+}$ significant at 15%.

A.3 Results for linear 2SLS estimation

A.3.1 Basic Model

Table 15: **2SLS, Sexual Relationship (estimated coefficients)**

	Males		**Females**		**All**	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexpartner_{11\text{-}22}$)						
$\Delta\ BMI_{1\text{-}10}$	-0.039^{+}	0.025	-0.012	0.061	-0.035^{+}	0.024
age	0.001	0.004	-0.008	0.009	-0.002	0.004
female	–	–	–	–	-0.182^{**}	0.072
$together_0$	0.437^{**}	0.105	0.577^{**}	0.131	0.479^{**}	0.077
BMI_0	-0.012^{+}	0.008	-0.006	0.014	-0.011^{+}	0.007
constant	0.822^{**}	0.418	0.806	0.654	0.890^{**}	0.346
first stage equation (dependent variable: $\Delta BMI_{1\text{-}10}$)						
$incentive\ 150_{1\text{-}4}$	-0.796^{**}	0.368	-0.727^{+}	0.503	-0.808^{**}	0.289
$incentive\ 300_{1\text{-}4}$	-0.997^{**}	0.403	-1.196^{**}	0.462	-1.103^{**}	0.298
$incentive\ 250_{5\text{-}10}$	-2.714^{**}	0.456	-1.382^{**}	0.502	-2.260^{**}	0.353
$incentive\ 500_{5\text{-}10}$	-2.031^{**}	0.401	-1.772^{**}	0.541	-1.877^{**}	0.310
age	0.004	0.021	-0.007	0.030	0.001	0.018
female	–	–	–	–	0.078	0.273
$together_0$	-0.490	0.416	0.275	0.435	-0.170	0.314
BMI_0	-0.082^{*}	0.046	0.012	0.039	-0.046^{+}	0.032
constant	3.566^{+}	2.217	-0.152	2.316	2.075	1.570
# of observations (first stage)	271		141		412	
# of observations (main equation)	103		53		156	
instrument relevance (*F*-statistic)	17.812		5.313		22.121	

Notes: ** significant at 5%; * significant at 10%; $^{+}$ significant at 15%; bootstrapped standard errors reported.

Table 16: **2SLS, Frequency of Sexual Intercourse (estimated coefficients)**

	Males		**Females**		**All**	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexfrequency_{11\text{-}22}$)						
$\Delta\ BMI_{1\text{-}10}$	-0.020	0.048	0.015	0.116	-0.027	0.045
age	-0.018^{**}	0.007	-0.014	0.017	-0.013^{+}	0.008
female	–	–	–	–	-0.303^{**}	0.132
$together_0$	0.409^{**}	0.171	1.096^{**}	0.239	0.686^{**}	0.140
BMI_0	-0.033^{**}	0.015	-0.016	0.024	-0.027^{**}	0.012
constant	3.225^{**}	0.678	1.720^{+}	1.170	2.546^{**}	0.617
first stage equation (dependent variable: $\Delta BMI_{1\text{-}10}$)						
$incentive\ 150_{1\text{-}4}$	-0.796^{**}	0.370	-0.727^{+}	0.489	-0.808^{**}	0.314
$incentive\ 300_{1\text{-}4}$	-0.997^{**}	0.395	-1.196^{**}	0.472	-1.103^{**}	0.305
$incentive\ 250_{5\text{-}10}$	-2.714^{**}	0.455	-1.382^{**}	0.506	-2.260^{**}	0.362
$incentive\ 500_{5\text{-}10}$	-2.031^{**}	0.392	-1.772^{**}	0.545	-1.877^{**}	0.313
age	0.004	0.021	-0.007	0.031	0.001	0.018
female	–	–	–	–	0.078	0.279
$together_0$	-0.490	0.412	0.275	0.436	-0.170	0.315
BMI_0	-0.082^{*}	0.045	0.012	0.040	-0.046	0.033
constant	3.566^{*}	2.166	-0.152	2.344	2.075	1.605
# of observations (first stage)	271		141		412	
# of observations (main equation)	99		53		152	
instrument relevance (*F*-statistic)	17.812		5.313		22.121	

Notes: ** significant at 5%; * significant at 10%; $^{+}$ significant at 15%; bootstrapped standard errors reported.

A.3.2 Conditional Model

Table 17: **2SLS, Sexual Relationship, cond. on success in weight-loss phase (est. coefficients)**

	Males		Females		All	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexpartner_{11\text{-}22}$)						
$\Delta\, BMI_{5\text{-}10}$	-0.149^{+}	0.097	0.315	0.554	-0.082	0.107
age	-0.003	0.007	0.012	0.038	-0.005	0.006
female	–	–	–	–	-0.098	0.096
$together_4$	0.341^{**}	0.139	0.273	0.534	0.422^{**}	0.106
BMI_4	-0.017	0.013	-0.046	0.047	-0.018^{+}	0.011
constant	1.318^{**}	0.600	1.381	1.559	1.370^{**}	0.451
first stage equation (dependent variable: $\Delta\, BMI_{5\text{-}10}$)						
$incentive\,250_{5\text{-}10}$	-1.417^{**}	0.407	-0.366	0.520	-1.034^{**}	0.323
$incentive\,500_{5\text{-}10}$	-0.992^{**}	0.405	-0.416	0.656	-0.738^{**}	0.339
age	0.004	0.019	-0.049	0.036	-0.014	0.017
female	–	–	–	–	0.116	0.295
$together_4$	-0.102	0.414	0.822	0.577	0.265	0.339
BMI_4	-0.030	0.041	0.080^{+}	0.050	0.012	0.032
constant	2.073	1.585	-0.245	2.570	1.012	1.361
# of observations (over all)	179		81		260	
# of observations (main equation)	65		32		97	
instrument relevance (*F*-statistic)	6.442		0.299		5.127	

Notes: ** significant at 5%; * significant at 10%; $^{+}$ significant at 15%; bootstrapped standard errors reported. All model equations estimated using only individuals who successfully lost body weight during month one to four.

Table 18: **2SLS, Freq. of Intercource, cond. on success in weight-loss phase (est. coefficients)**

	Males		Females		All	
	Est. Coef.	S.E.	Est. Coef.	S.E.	Est. Coef.	S.E.
main equation (dependent variable: $sexfrequency_{11\text{-}22}$)						
$\Delta\, BMI_{5\text{-}10}$	-0.219	0.203	0.438	1.214	-0.163	0.233
age	-0.019^{*}	0.011	0.010	0.071	-0.017	0.012
female	–	–	–	–	-0.094	0.181
$together_4$	0.444^{*}	0.247	0.763	1.169	0.735^{**}	0.212
BMI_4	-0.040^{*}	0.023	-0.080	0.102	-0.038^{*}	0.020
constant	3.481^{**}	0.950	2.880	3.329	3.101^{**}	0.860
first stage equation (dependent variable: $\Delta\, BMI_{5\text{-}10}$)						
$incentive\,250_{5\text{-}10}$	-1.417^{**}	0.397	-0.366	0.535	-1.034^{**}	0.322
$incentive\,500_{5\text{-}10}$	-0.992^{**}	0.412	-0.416	0.653	-0.738^{**}	0.336
age	0.004	0.019	-0.049	0.037	-0.014	0.018
female	–	–	–	–	0.116	0.294
$together_4$	-0.102	0.407	0.822	0.582	0.265	0.353
BMI_4	-0.030	0.041	0.080^{+}	0.050	0.012	0.033
constant	2.073	1.570	-0.245	2.645	1.012	1.387
# of observations (over all)	179		81		260	
# of observations (main equation)	63		32		95	
instrument relevance (*F*-statistic)	6.442		0.299		5.127	

Notes: ** significant at 5%; * significant at 10%; $^{+}$ significant at 15%; bootstrapped standard errors reported. All model equations estimated using only individuals who successfully lost body weight during month one to four.

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