The effect of physical activity on changes in weight and bone mineral density following bariatric surgery

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Thesis for the degree of Master of Science
University of Iceland
The Faculty of Sport, Leisure Studies and Social Education
Department of Sport- and Health Sciences
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This thesis equals 60 ECTS credits for the degree of Masters of Science in Sport- and Health Sciences.

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This thesis is a part of a research-based study for the degree of Masters of Science in Sport- and Health Sciences. The thesis equals 60 ECTS credits and it is based on a prospective study of patients undergoing gastric bypass surgery in Iceland during 2010-2012. The study is a part of more extensive research conducted by Diana Óskarsdóttir and Gunnar Sigurdsson, in cooperation with Landspitali University Hospital and Reykjalundur Rehabilitation Centre. I would like to thank the mentors that made this thesis possible, Sigríður Lára Guðmundsdóttir associate professor at the University of Iceland and Diana Óskarsdóttir assistant professor. I would like to give them very appreciative thanks for all their work and instructive mentoring in this project. I also thank the participants in the study, without them this project would not have been possible. Last but not least I would like to thank my family and friends for being supportive, patient and understanding during this project.

This thesis is written by me undersigned. I have studied the Scientific Protocol of the University of Iceland. Ethics, criteria standards, gathering of information and the interpretation of the results in this research was handled with the utmost integrity. I refer to all materials that I have gathered from other studies or articles, whether in the case of tips, pictures, content or wording. I want to thank all that have help me with this thesis and I take full responsibility on everything that could have been wrongly written. This I confirm with my signature.

Reykjavík, October 31st, 2016

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Abstract

Bariatric surgery is considered the most effective treatment for severe obesity, leading to weight loss with mean reductions of about 60% of excess weight or 14 kg/m² BMI units, marked improvements in associated comorbidities such as hypertension, diabetes, obstructive sleep apnea, in addition to a decrease in mortality and large reductions in health-care costs.

The purpose of this study was to assess if physical activity could impact weight loss and BMD loss in subjects undergoing bariatric surgery, based on a 2-year short-term cohort study. Secondary aims were to assess long term weight loss and changes in BMD. Subjects were men and women, who underwent obesity treatment and gastric bypass surgery at Reykjalundur during 2010-2012, a total of 70 participants (aged 24-65 years old), 11 men and 59 women. Height, weight, bone mineral density and physical activity were measured.

After correcting for age and gender, a significant average weight loss from baseline to 12 months follow up for women 35.31 kg and men 41.43 kg (p<0.01). However, at 24 months follow up, men had gained on average 2.62 kg in comparison with the 12 months follow up (p<0.05) but women kept losing weight. There was significantly difference (p<0.01) from baseline to 12 months follow up, in BMD loss at wards triangle, trochanter, total hip and total spine for men but not at femoral neck but at all measurement sites for women (p<0.01 for all). At 24 months follow up, BMD was significantly lower than at baseline and at 12 months follow up at all measurement sites both for men and women (p<0.01). No significant correlations were found between weight loss and changes in BMD at any measurement site for men. A weak-to-moderate significant correlation were found between weight loss and changes in BMD between baseline and 12 months follow up for women in femoral neck, wards triangle, trochanter and total hip (p<0.001). Change in weight between baseline and 24 months was also weakly-to-moderately and significantly correlated with BMD changes in femoral neck, trochanter and total hip (p<0.001). No significant correlations were
found between change in weight between 12 and 24 months and change in BMD during the same period. The differences in weight and BMD changes did not differ significantly across the categories of physical activity.

In conclusion, long term weight loss correlated with BMD loss following bariatric surgery, but the role of physical activity in these processes remains largely unknown. Many questions have risen, in particular related to the recommended intensities of physical activity. Physical activity did not correlate with weight loss or BMD at any point after the surgeries, therefore further research is required to find out what type and intensity of physical activity will be most effective in reducing loss of BMD and enhancing weight loss after bariatric surgery.
Ágrip

Hjáveituðgerðir eru taldar áhrifamestu meðferðir við offitu, þar sem þyngdartap getur orðið allt að 60% af viðbótarþyngd eða 14 kg/m² BMI einingar og samfara því getur dregið úr einkennum eða áhættu á sjúkdómum eins og háþrýstingi, sykursýki og kæfisvefni, sem og lækkunar í dánartiðni og þar með haft áhrif til lækkunar á heilbrigðískostnaði.


Þyngdartap á fyrstu 12 mánuðunum var marktækt hjá bæði konum og körlum (p<0,01), karlar léttust að meðaltali um 41,43 kg en konur 35,31 kg. Karlar þyngdust um 2,62 kg frá 12 mánaða skoðun til 24 mánaða skoðunar, en konur héldu áfram að léttast. Það var marktækur munur (p<0,01) á beinþéttni frá því fyrir aðgerð til 12 mánaða skoðunar á þremur mælistöðum, wards triangle svæðinu, lærhnútur, mjöðum og hrygg hjá körlum en einnig var marktækur munur hjá konum á fjórða staðnum eða á lærleggshálsl. Eftir 24 mánaða eftirfylgni var beinþéttni marktækt lærlegri en fyrir aðgerð á öllum mælistöðum bæði hjá körlum og konum (p<0,01). Engin marktæk tengls voru á milli þyngdartaps og breytingar í beinþéttni á öllum mælistöðum/tínum hjá körlum. En marktæk tengls voru hjá konum frá því fyrir aðgerð til 12 mánaða skoðunar á milli þyngdartaps og breytingar í beinþéttni í lærleggshálsl, wards triangle svæðinu, lærhnúturum og mjöðum (p<0,001). Marktæk tengls voru einnig frá því fyrir aðgerð til 24 mánaða skoðunar hjá konum á milli þyngdartaps og breytingar í beinþéttni í lærleggshálsl, lærhnúturum og mjöðum (p<0,001). Þá hafði hreyfing ekki marktæk áhrif á þyngdartap eða breytingu á beinþéttni.
Í þessum hópi sjúklinga sem fóru í hjáveituaðgerð, voru marktæk tengsl milli þyngdartaps og beintaps en beintap helt áfram eftir að hægðist á þyngdartapi. Hlutverk hreyfingar í þessu samhengi er óljóst. Nánari rannsókna er þörf á til að varpa ljósi á hvort og þá hvers konar hreyfing getur nýst til minnkunnar á beintapi og viðhaldið þyngdartapi eftir hjáveituaðgerð.
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1 Introduction

In today’s society, obesity has become one of the major health problems. Since the 1980s, the number of obese individuals has increased drastically, reaching the figure of more than 600 million people in the world in 2014 and still is an increasing global epidemic (World Health Organization, 2016, Lehnhoff M. et al., 2007). Obesity is defined as when body mass index (BMI) is higher than 30.0. The BMI is an index of weight for height that is commonly used to classify overweight and obesity in adults. It is defined as a person’s weight in kilograms divided by the square of height in meters (kg/m²). BMI can be used as a screening tool but is not diagnostic of the body fatness or health of an individual. The most commonly used categories of BMI are:

- if BMI is 18.5 to 24.9, it is classified in the normal or healthy weight range,
- if BMI is 25.0 to 29.9, it is classified in the overweight range,
- if BMI is 30.0 or higher, it is classified in the obese range.

Currently, the overall prevalence of obesity (BMI ≥30 kg/m²) in the USA is 33% and is expected to rise to about 50% by 2030 (Wang Y.C. et al., 2011). The main public health concern is that individuals with a BMI of ≥40 kg/m² are the most rapidly growing group in the obese population. In fact, a 50% increase in the number of individuals with a BMI greater than 40 kg/m² and a 75% increase in the prevalence of BMI greater than 50 kg/m² has been predicted (Wang Y.C. et al., 2011). In comparison, an Icelandic study showed that 32.2% of women were overweight and 21.3% were in the obese category in 2007 and among men, 47.7% were overweight and 18.9% in the obese range (Valdimarsdóttir M. et al., 2009).

Obesity causes many health problems, for example obese individuals have a higher risk of severe chronic diseases such as cancer, hypertension, cardiovascular diseases, type II diabetes and hyperlipidemia (Wang Y.C. et al., 2011). In addition, there are about 2.6 million obesity related deaths every year (World Health Organization, 2016). Lifestyle approaches e.g. weight management, increased physical activity, dietary
modification, and behavior modification have been shown to produce weight loss in the short term but long-term maintenance has been difficult to attain (Wing R.R., Hill J.O., 2001). Bariatric surgery is considered the most effective treatment for severe obesity to achieve long-term weight loss, resulting in a loss of at least 50% of excess weight along with a significant improvement in obesity-related comorbidities (Buchwald H. et al., 2009, Sjöström L. et al., 2007).

Body weight is a strong determinant of bone mineral density (BMD) at multiple skeletal sites and it also influences bone turnover. A meta-analysis has shown that high BMI is protective against fractures including osteoporotic fractures and non-osteoporotic hip fractures in women and men (De Laet C. et al., 2005). Cross-sectional studies have shown that thinner women have lower bone mineral density, particularly at weight bearing sites such as the spine and hip compared to women with higher body mass (Orwoll et al., 1996, Glauber et al., 1995, Edelstein et al., 1993, Felson et. al, 1993). Furthermore, patients who have undergone an operation for obesity such as Roux-en-Y gastric bypass (RYGB) had a reduction in BMD at one year follow up (Johnson J.M. et. al., 2005). The reduced BMD experienced by patients undergoing this procedure may be attributed to substantial weight loss, and maybe intensified by the damage of calcium and vitamin D absorption that makes individuals more sensitive to hypocalcemia and secondary hyperparathyroidism (Slater G.H. et al., 2004, Goldner W.S. et al., 2002). However, it has to be kept in mind that studies on the effects of bariatric surgeries on bone metabolism have had a short follow up time, therefore it is necessary to look at long-term changes in bone density following bariatric surgery.
2 Bariatric surgery

Bariatric surgery is considered the most effective treatment for severe obesity, leading to mean weight loss of about 60% of excess weight or 14 kg/m² BMI units and marked improvements in associated comorbidities such as hypertension, diabetes and obstructive sleep apnea, as well as a decrease in mortality and large reductions in health-care costs (Elaine W.Y.U., Christou N.V, 2004, Buchwald H, 2004, Sampalis J.S., 2004). Bariatric surgeries have been performed in Iceland with good results (Buchwald & Oien, 2013). In 2011, a total of 106 surgeries were performed, representing 0.0332% of the population. The roux en Y Gastric bypass was the most common procedure, or 83 operations (Buchwald & Oien, 2013). In comparison, 101,645 procedures were performed in the USA and Canada, representing 0.0326% of the population, somewhat lower proportions were reported for Finland or 0.0196% but higher for Sweden 0.0899% (Buchwald & Oien, 2013).

There are four types of bariatric surgery: roux en Y Gastric bypass (RYGB), vertical banded gastroplasty (VBG), adjustable gastric band (Band) and biliopancreatic diversion (BPD) with duodenal switch. Roux-en-Y gastric bypass surgery (RYGB) is considered the gold standard procedure and is the most commonly performed bariatric procedure worldwide (Freire et al., 2012). The procedure of RYGB is performed in two steps, first a small stomach pouch, approximately one ounce or 30 milliliters in volume, is created by dividing the top of the stomach from the rest of the stomach. In the second step, the first portion of the small intestine is divided, and the bottom end of the divided small intestine is brought up

![Figure 1 – Four different methods of bariatric surgeries](American Society for Metabolic and bariatric surgery, 2016)
and connected to the newly created small stomach pouch. The final step of the procedure is completed by connecting the top portion of the divided small intestine to the small intestine further down so that stomach acids and digestive enzymes from the bypassed stomach and first portion of small intestine will eventually mix with the food (American Society for Metabolic and bariatric surgery, 2015).

The second most common procedure is a laparoscopic adjustable gastric band. This procedure involves an inflatable band that is placed around the upper portion of the stomach, creating a small stomach pouch above the band, and the rest of the stomach below the band, which controls the rate of emptying of the pouch and meal capacity (American Society for Metabolic and bariatric surgery, 2016). Another procedure, preferred by a number of surgeons, is the biliopancreatic bypass which combines a limited gastrectomy with a log Roux limb intestinal bypass that creates a small common channel. This particular procedure can be combined with a duodenal switch, which maintains continuity of the proximal duodenum with the stomach and uses a long limb Roux-en Y bypass to create a short common distal channel (Albaugh V.L. et al., 2016).

Despite the obvious advantages of bariatric surgery such as drastic weight loss, reduced risk of comorbidities, improved quality of life and lower risk of metabolic disease, there are side-effects (Freire et al., 2012). Complications during the early stages may include internal bleeding, infection, and respiratory problems and could lead to death (Thomas & Agrawal, 2012). In the long-term, a condition known as “dumping syndrome” can occur after eating too quickly or eating foods which are high in refined sugars (Concors S.J. et al., 2016). Symptoms of the dumping syndrome could be sweating, nausea, flushing, lightheadedness and fast heart rate. Further, absorption of calcium and iron is decreased because the duodenum is bypassed. Lack of these minerals can lead to anemia and bone disease so it is recommend taking vitamins and other supplements after the procedure (Concors S.J. et al., 2016).
3  Bone mineral density

The skeleton has two major roles, first and most importantly it is calcium storage for homeostasis. The skeleton contains 99% of all calcium found in the human body and calcium is critical for all life functions. The second role of the skeleton is to provide structural support for the body (Lanyon, 1993). The bones act as levers during muscle contraction and can withstand forces many times that of body weight during movement. It is very important that bones have adequate strength to resist bending and fracture during mechanical loading. When bone bends due to loading it appears that bone cells such as the osteocytes and osteoblast detect stretch, fluid flow, and/or electrical currents. These cells, osteocytes and osteoblasts transduce the mechanical signal into a cellular response that over time initiates an adaptive response where the bone adjusts to loading by increasing bone formation and mass in areas of outstanding strain and reducing mass in areas of least strain (Lanyon, 1993).

There are two major kinds of bone, trabecular (spongy) and cortical. Trabecular bone is predominant in flat or cuboid bones and at the ends of long bones. It consists of an irregular sponge-like network of mineralized plates called trabeculae. Cortical bone is predominant in the skull and the shafts of long bones. A central canal is surrounded by concentric layers of mineralized collagen that creates a dense compact tissue, suitably designed to withstand mechanical stresses (Marcus, Feldman, Kelsey, 2001).

Bone size is genetically determined but mechanical forces and hormonal stimuli affect the genetic potential (Cawsey S. et al., 2015). Bone mineral density (BMD) is a measurement of the amount of calcium and other minerals in a segment of a bone, a higher mineral content is associated with lower risk of fracture although fractures also occur in those with normal BMD as bone strength also depends on bone geometry, microarchitecture and material properties (Schuit S.C. et al., 2004, Stone K.L. et al., 2003, Seeman E., 2002). BMD is measured to diagnose osteoporosis or to monitor its treatment. If BMD is considerably lower than in age and gender-matched individuals, the risk of fractures is increased (Cawsey S. et al., 2015). There are several methods to
measure bone density and size. These methods are capable of measuring both whole body and also sectional sites. The most common method for measuring bone density is Dual energy x-ray absorptiometry (DEXA). Low energy X-rays are sent from two different sources through the bone being tested. The denser the bone is, the less X-rays get through to the detector. Subjects lie on their back and the device is programmed to measure whole body, lumbar spine, hip or forearm bone mineral density. The device measures the radiation that passes through body regions and can calculate bone mineral content, body fat mass and lean body mass. DEXA is often chosen because of low radiation and low cost but other methods may provide additional information. Bone architecture can be estimated by quantitative computed tomography (QCT) measures. QCT measures the full cross-sectional area of the bone but DEXA only reports density in grams of mineral per area of bone, using only bone width and assuming consistent bone shape. QCT has a much higher radiation and cost, but provides measures of trabecular and cortical bone separately from the same region (Smith R.T., Cullen D.M., 2004).

Bone mass increases during childhood and puberty until peak bone mass (the highest amount of bone mass achieved during the lifespan at a given skeletal site) is reached during young adulthood. After that, bone mass declines with age, with rapid decline in women during and immediately after menopause years (Hind K., Burrows M., 2007). It is estimated that 90% of adult bone mass is achieved by the end of puberty (Matkovic V., 1994, Tylavsky F., 1989), with the remainder of peak bone mass accumulating through the twenties (Recker R.R. et al., 1992, Davee A. et al., 1990). Although genetics play a major role in deciding potential peak bone mass and age related bone loss, its accrual and maintenance also depend upon lifestyle factors such as weight bearing exercise and calcium intake (Smith R.T., Cullen D.M., 2004).

Body weight is a strong determinant of BMD at multiple skeletal sites and also influences bone turnover. Furthermore, a meta-analysis reported that high body mass index (BMI) was protective against fractures in men and women (De Laet C. et al., 2005). Results from several cross-sectional studies have shown that women who are thinner have lower bone density, particularly at weight bearing sites such as the spine and hip compared to women with higher body mass (Orwoll et al., 1996, Glauber et al.,
1995, Edelstein et al., 1993, Felson et al., 1993). Prospective population studies have reported that changes in weight were linked to concurrent changes in BMD at the hip in older men and women (Hannan M.T. et al, 2000, Dennison E. et al., 1999, Nguyen T.V. et al., 1998). Low body weight is a strong risk factor for fractures at the hip in older women (Ensruds K.E., 2003). Moreover, studies have indicated that losing weight between early or middle adulthood and old age increases the risk of hip fractures in elderly women (Langlois J.A et al, 2001, Laglois J.A. et al., 1996, Cummings S.R. et al., 1995).

Patients who have undergone an operation for obesity such as RYGB have a reduction in BMD at one year follow up (Johnson J.M. et al., 2005). The bone mineral density reduction experienced by patients undergoing this procedure may be attributed to substantial weight loss, and is probably intensified by damage of vitamin D absorption and calcium that could lead to hypocalcemia and secondary hyperparathyroidism (Slater G.H. et al., 2004, Goldner W.S. et al., 2002). Studies on the influence of bariatric surgery on BMD and bone turnover are mainly limited to six months to one year follow-up time. These studies have shown that at one year follow up, there is an increase in bone resorption and a reduction in BMD, mainly at the hips (Costa T. L. et al., 2015, Casagrande D.S. et al., 2012, Fleischer J. et al., 2008).
4 Physical activity

Physical activity is defined as “any bodily movement produced by skeletal muscles that requires energy expenditure – including activities like working, playing, carrying out household chores, travelling and engaging in recreational pursuits” (Caspersen C. et al., 1985). There is strong evidence that individuals, both women and men, who are more physically active have lower rates of all cause-mortality, coronary heart disease, high blood pressure, stroke, type 2 diabetes, metabolic syndrome and depression than inactive individuals (Puzziferri N. et al., 2014, Sjöström L., 2012, Stefater M.A. et al., 2012, Herpertz S. et al., 2003). Also, these individuals are likely to have lower risk of hip or vertebral fractures, exhibit a higher level of cardiorespiratory and muscular fitness and are more likely to achieve weight maintenance and have a healthier body composition (World Health Organization, 2015).

The World Health Organization (WHO) has published official recommendations for physical activity for people of all ages (World Health Organization, 2015). In order to improve muscular and cardiorespiratory fitness, bone health, reduce the risk of chronic diseases and depression for the ages of 18-64, it is recommended:

1. “To perform at least 150 minutes of moderate-intensity aerobic physical activity throughout the week or at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week”.

2. “Aerobic activity should be performed in bouts of at least 10 minutes duration”.

3. “To achieve health benefits, adults should increase their moderate intensity aerobic physical activity to 300 minutes per week, or engage in 150 minutes of vigorous-intensity aerobic physical activity per week”.

4. “Muscle-strengthening activities should be done involving major muscle groups on 2 or more days a week” (World Health Organization, 2015).
The development of new technologies in today’s society has enabled people to reduce the amount of physical labor in all kinds of tasks in their daily lives. Technologies that have negatively influence on physical activity are for example mechanical methods of transportation, electronic entertainment, computers, televisions, the internet, and wireless communication devices. The aim behind these technological advancements is to both improve productivity and effectively reduce the disabilities and hardships associated with physical labor. Evolution has however dictated that stimulation through frequent physical activity is required for the body systems to adequately develop and function in an optimal fashion (Booth F.W. et. al., 2008). Physical activity in general has decreased worldwide, and in the year 2009 physical inactivity was indicated as the fourth leading risk factor for non-communicable diseases, reported to cause more than 3 million preventable deaths (World Health Organization, 2015). A third of all adults in the world do not reach public health guidelines for recommended physical activity (Hallal P., Andersen L.B., et al. 2012). Inactivity is more common among women (mean proportion of 33.9%) than in men (mean of 27.9%) in most countries, and older adults are less active than younger adults. There are some gaps in studies of physical activity, e.g. no data are available from about a third of countries in the world, mostly countries of low and middle income in Africa and central Asia (Hallal P., Andersen L.B., et al. 2012).

The most common and simplest method to estimate levels of physical activity in large populations has until now been a subjective measure; self-administered or interview based questionnaire. In the late 1990s an international group of academics developed a standardized instrument—The International Physical Activity questionnaire (IPAQ) to assess physical activity worldwide, with validity and reliability measures taking place in 12 countries (Craig C.L., Marshall A.L., Sjostrom M., et al. 2003). The improvement of IPAQ and subsequent work leading to the global physical activity questionnaire (GPAQ) provided very important measurements to support monitoring worldwide (Bull F.C., Maslin T.S., Armstrong T., 2009). Physical activity is rather complex to assess but the questionnaires are both sufficient and economical measurement tools of physical activity in large groups (Bull F.C., Maslin T.S., Armstrong
Physical activity consists of several factors and attributes such as type, intensity, frequency and duration of sessions, and occurs in many different fields. As physical activity questionnaires are subjective methods, the results obtained could depend on the respondent’s cognition. The results could also be influenced by interviewer bias, the day of the week, and if the questionnaire is combined with other physical activity measurements (Hallal P., Andersen L.B., et al., 2012). Due to these limitations, researchers sometimes combine subjective and objective measures of physical activity. Progression in new technologies and measurement methods, particularly accelerometers, show good promise for future surveillance of physical activity. Also if equipment costs continue to decrease, these devices have potential practical use to measure physical activity in large groups (Hallal P., Andersen L.B., et al. 2012).

4.1 Physical activity and BMD

Studies have shown that physical activity seems to play an important role in increasing bone mass during childhood and in the early adult years. Bone mass is higher in children who are active, especially in children who take part in exercise that generates high impact forces (e.g. gymnastic and ballet) than inactive children or those who participate in exercise that has lower impact forces (e.g. walking) or exercise that are not weight bearing (e.g. swimming) (Gunter K.B. et al., 2012). In middle-age and old people, the benefits of physical activity may be reflected by a reduction in the rate of bone loss, rather than gain in bone mass. Even high impact levels of physical activity do not prevent the menopause-induced loss of bone mass in women. A mixture of types of exercise, especially high intensity resistance training, can be effective in maintaining bone mass in the elderly (Kohrt, W.M, Bloomfield, et al., 2004).

Results from multiple small randomized controlled trials and large observational studies have resulted in the following exercise instruction to help preserve bone health during adulthood:

✓ **Mode**: Weight-bearing endurance activities such as walking, jogging, stair climbing, activities that involve jumping such as volleyball/basketball and weight lifting.
✓ **Intensity:** moderate to high, in terms of bone-loading forces.

✓ **Duration:** Combination of weight-bearing endurance activities, resistance and jumping exercise that targets all major muscle groups in 30-60 minutes.

✓ **Frequency:** 3-5 times per week, some weight-bearing endurance activities and resistance exercise 2-3 times per week (Kohrt, W.M, Bloomfield, et. al., 2004).

A meta-analysis conducted by researchers at Leeds Metropolitan University, showed that mixed loading exercise programs, combining jogging with other low-impact loading activity reduced postmenopausal bone loss at the spine and hip resulted in the most favorable outcome. Programs that are mixed with impact activity and high magnitude exercise also seem to be effective (Martyn-St James M., Carroll S., 2008).

### 4.2 Physical activity and bariatric surgeries

Physical activity is considered an important element in weight control and health programs including weight loss after bariatric surgery (Farah A. et al., 2014). It is important to increase or maintain a high-level of physical activity post-surgery because it could provide more health benefits and maintain lower weight, independent of BMI. In addition it could decrease the loss of fat-free mass, which is related to muscle fatigue, and decrease all-cause mortality (Iannelli A. et al., 2013, Szulc P. et al., 2010, Jakicic J.M. et al., 2008). The very large majorities of bariatric surgery candidates are not physically active enough and often fail to increase physical activities post-surgery despite of great weight loss (Bond D.S. et al., 2010, King W.C. et al., 2010).
5 Aim of the study

The primary aim was to examine if there is an association between physical activity and changes in weight and bone mineral density following bariatric surgery, based on a 2-year short-term cohort study.

A secondary aim was to examine the development in weight and bone mineral density following bariatric surgery.
6 Methods

6.1 Study design

The study was a prospective study of patients undergoing gastric bypass surgery in Iceland during 2010-2012. Patients were invited to take part in a study of changes in body composition and bone mineral density during a 2-year follow up time after surgery. All patients were also asked to fill in a questionnaire regarding physical activity, use of medications and vitamins. Recruitment of participants was an ongoing process during the period, each individual being invited to participate as their gastric bypass surgery was scheduled. All measurements took place at the Icelandic Heart Association. The patients were given vitamin D tablets to ensure adequate intake. The study design was approved by the National Bioethics Committee and Icelandic Radiation Safety Authority.

6.2 Subjects

Patients, men and women, who underwent obesity treatment and gastric bypass surgery at Reykjalundur during 2010-2012, a total of 70 participants (aged 24-65 years old), agreed to take part in the study. All subjects signed an informed consent form (see appendix A).

6.3 Measures of bone mineral density and body composition

Bone mineral density was measured by DEXA using a GE LUNAR scanner at baseline, 12 months after the surgery and after 24 months. BMD was measured in the femoral neck, the total hip (calculated by the software by adding femoral neck, trochanter and intertrochanter area), and lumbar spine L1-L4. All measures were done at the Icelandic Heart Association by a single radiologist.
6.4 Measures of physical activity

The participants completed the International Physical Activity Questionnaire (IPAQ) at each measurement time, reporting their physical activity at work and leisure time and method of transportation. The questionnaire includes questions about the intensity and duration of each activity as well as on how much time is spent being sedentary (see appendix B).

Metabolic equivalent tasks (METs) were calculated as the outcome of the questionnaire about physical activity. It is considered one of the easiest methods for recording the intensity of a physical activity. A single MET is defined as the resting metabolic rate, the amount of oxygen consumed at rest, sitting quietly in a chair, requiring approximately 3.5 ml O$_2$/kg/min (1.2 kcal/min for a 70-kg person). Work at 2 METS requires twice the resting metabolism or 7.0 ml O$_2$/kg/min and three METS requires three times the resting metabolism (10.5 ml O$_2$/kg/min), etc. (Jetté M. et al., 1990). In the current study, METs were calculated per week for total occupation METs, total leisure METs and total METs (including occupational, leisure time and transport physical activity).

In addition to treating physical activity on a continuous scale based on METs scores, subjects were categorized into three groups by weekly duration of moderate-to-high intensity physical activity, none (0 minutes per week), low (1-149 minutes per week) and moderate (150 minutes or more per week), the last group therefore confirming to official recommendations of physical activity levels per week.

6.5 Other measures

Body weight and height were measured with the subject standing without shoes, at baseline, after 12 months and 24 months. Height and weight were used to calculate the body mass index (BMI), a measure of weight in kilograms divided by the square of height in meters.

6.6 Statistical analyses

Statistical analyses were done by using SPSS 23.0 (Statistical Package for the Social Sciences). Descriptive analyses included summary statistics for all variables. Differences
in weight and BMD were calculated for three periods; a) between baseline and 12 months, b) between baseline and 24 months and c) between 12 and 24 months. Changes in weight and BMD were calculated as percentages (%). Changes were compared by using a paired t-test for differences in means of continuous variables. Linear regression was used to assess the association between continuous variables. ANOVA was used to determine differences between groups of physical activity (none, low, moderate) regarding changes in BMD and weight post-surgery. All analyses were run separately for males and females and adjusted for age.
7 Results

7.1 Study subjects

A total of 70 subjects (aged 24-65 years old), or all of those invited, participated in the baseline measure (immediately before the surgery) and at the 12 months follow up. Sixty two remained at 24 months after the surgery as shown in Figure 2.

![Diagram showing number of participants over the research period]

**Figure 2 - Number of participants over the research period**

7.2 Characteristics of the study participants

Descriptive subjects characteristics are presented in table 1, including mean values for weight, BMD and physical activity at all measurements.
7.2.1 Weight loss

Average weight loss from baseline to 12 months follow up was 41.43 kg for men and 35.31 kg for women, a statistically significant change (p<0.01) for both genders. At 24 months follow up however, the men had gained on average 2.62 kg in comparison to the 12 months follow up (p<0.05), whereas the women kept losing weight, on average 1.4 kg from the 12 month follow up to 24 months follow up.

7.2.2 Changes in DXA measurements

From baseline to 12 months follow up there was a significant BMD loss at the wards triangle, trochanter, total hip and total spine (p<0.01) but not at the femoral neck for men. During these first 12 months, there were significant reductions in BMD at all measurement sites for women (p<0.01 for all). BMD was significantly lower at 24 months follow up compared to baseline and at 12 months follow up at all measurement sites both for men and women (p<0.01). Individual changes in BMD at all measurement sites by subjects’ age are shown on graphs in appendix C.

7.2.3 Changes in physical activities

A significant decrease leisure time METs and total METs per week was observed from baseline to 24 months follow up for men (p<0.05), and a significant increase in occupational total METs for women from baseline to 24 months follow up (p<0.05). There were no significant changes in minutes of moderate and vigorous physical activity per week from baseline to 12 months follow up or to 24 months follow up. At baseline, 23 subjects were classified as doing no moderate to physical activity, 18 had a low level of activity and 29 had moderate level of activity. At 12 months follow up these numbers were 24, 20 and 25 and at 24 months 30, 13, and 19 subjects respectively.
Table 1: Characteristics of the 70 study participants

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th></th>
<th>Female</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline (SD)</td>
<td>12 month follow up (SD)</td>
<td>24 month follow up (SD)</td>
<td>Baseline (SD)</td>
</tr>
<tr>
<td></td>
<td>(n=11)</td>
<td>(n=11)</td>
<td>(n=9)</td>
<td>(n=59)</td>
</tr>
<tr>
<td>Age</td>
<td>44.67 (12.27)</td>
<td>40.34 (9.22)</td>
<td>112.81 (17.33) (\text{b})</td>
<td>116.34 (13.46)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>151.62 (19.26) (\text{b})</td>
<td>110.19 (12.43) (\text{b})</td>
<td>116.34 (13.46) (\text{b})</td>
<td>81.03 (11.99) (\text{b})</td>
</tr>
<tr>
<td>Body mass index (BMI)</td>
<td>45.81 (6.01)</td>
<td>33.48 (5.28) (\text{b})</td>
<td>34.45 (7.50) (\text{b}) (\text{c})</td>
<td>41.32 (5.03)</td>
</tr>
<tr>
<td>Femoral neck BMD (g/cm(^2))</td>
<td>1.16 (0.16)</td>
<td>1.13 (0.13) (\text{b})</td>
<td>1.06 (0.14) (\text{b}) (\text{c})</td>
<td>1.05 (0.12) (\text{b}) (\text{c})</td>
</tr>
<tr>
<td>Ward BMD (g/cm(^2))</td>
<td>0.93 (0.18)</td>
<td>0.87 (0.15) (\text{b}) (\text{c})</td>
<td>0.79 (0.16) (\text{b}) (\text{c})</td>
<td>0.88 (0.15) (\text{b}) (\text{c})</td>
</tr>
<tr>
<td>Trochanter BMD (g/cm(^2))</td>
<td>1.03 (0.12)</td>
<td>0.96 (0.11) (\text{b}) (\text{c})</td>
<td>0.88 (0.09) (\text{b}) (\text{d})</td>
<td>0.96 (0.13)</td>
</tr>
<tr>
<td>Total hip BMD (g/cm(^2))</td>
<td>1.24 (0.14)</td>
<td>1.16 (0.13) (\text{b}) (\text{c})</td>
<td>1.08 (0.11) (\text{b}) (\text{c})</td>
<td>1.19 (0.14)</td>
</tr>
<tr>
<td>Total Spine BMD (g/cm(^2))</td>
<td>1.40 (0.15)</td>
<td>1.34 (0.17) (\text{b}) (\text{c})</td>
<td>1.29 (0.20) (\text{b}) (\text{c})</td>
<td>1.33 (0.16)</td>
</tr>
<tr>
<td>Total occupational METs per week</td>
<td>3,071.09 (7,776.62)</td>
<td>807.46 (2,500.83)</td>
<td>100.83 (246.73)</td>
<td>1,082.48 (2,395.43)</td>
</tr>
<tr>
<td>Total leisure METs per week</td>
<td>2,109.14 (1,845.97)</td>
<td>819.00 (988.17)</td>
<td>671.22 (765.62) (\text{a})</td>
<td>1,422.21 (1,279.99)</td>
</tr>
<tr>
<td>Total METs per week</td>
<td>7,227.86 (7,996.08)</td>
<td>2,975.73 (2,949.34)</td>
<td>1,524.61 (999.12) (\text{a})</td>
<td>4,667.98 (4,591.67)</td>
</tr>
<tr>
<td>Moderate and vigorous physical activity per week (min)</td>
<td>245.91 (244.32)</td>
<td>77.73 (89.23)</td>
<td>62.22 (78.23)</td>
<td>141.02 (192.11)</td>
</tr>
</tbody>
</table>
7.3 Percent changes in weight and BMD

Percent changes in weight and BMD between measurements are presented in table 2. Negative numbers in the table imply weight or bone loss while a positive number refers to weight gain. There was a decrease in mean BMD at all measurement sites.

Table 2. Percent changes (SD) in weight and BMD from baseline to 12 and 24 months

<table>
<thead>
<tr>
<th></th>
<th>Male Percent change from baseline to 12 month (SD)</th>
<th>Male Percent change from baseline to 24 month (SD)</th>
<th>Female Percent change from baseline to 12 month (SD)</th>
<th>Female Percent change from baseline to 24 month (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>-26.63 (9.10)</td>
<td>-23.12 (14.02)</td>
<td>4.49 (5.78)</td>
<td>-30.36 (6.23)</td>
</tr>
<tr>
<td>Femoral neck BMD</td>
<td>-2.44 (4.57)</td>
<td>-6.15 (3.42)</td>
<td>-5.07 (2.48)</td>
<td>-7.13 (3.60)</td>
</tr>
<tr>
<td>Wards BMD</td>
<td>-6.8 (4.31)</td>
<td>-11.34 (4.62)</td>
<td>-6.69 (6.15)</td>
<td>-9.35 (4.76)</td>
</tr>
<tr>
<td>Trochanter BMD</td>
<td>-7.04 (4.32)</td>
<td>-11.85 (4.68)</td>
<td>-4.96 (4.20)</td>
<td>-9.94 (4.36)</td>
</tr>
<tr>
<td>Total hip BMD</td>
<td>-5.94 (2.54)</td>
<td>-10.34 (3.44)</td>
<td>-4.7 (2.43)</td>
<td>-9.12 (3.20)</td>
</tr>
<tr>
<td>Total Spine BMD</td>
<td>-4.22 (2.88)</td>
<td>-7.23 (4.20)</td>
<td>-3.10 (2.41)</td>
<td>-4.21 (4.25)</td>
</tr>
</tbody>
</table>

7.4 Correlations coefficients between weight loss and changes in BMD

Correlations coefficients between weight loss percentage and percentage changes in BMD are shown in table 3. No significant correlations were found between weight loss and changes in BMD at any measurement site for men. For women, a weak-to-moderate significant correlation was observed between change in weight between baseline and 12 months follow up and BMD changes in femoral neck (r=0.353), wards triangle (r=0.384), trochanter (r=0.499) and total hip (r=0.535) (p<0.001 for all). Change in weight between baseline and 24 months was also weakly-to-moderately and significantly correlated with BMD changes in femoral neck (r=0.377), trochanter (r=0.420) and total hip (r=0.471) (p<0.001 for all). No significant correlations were found between change in weight between 12 and 24 months and change in BMD during the same period. Changes in BMD in the spine were not correlated with changes in weight.
Table 3. Correlation coefficients between weight loss and changes in BMD

<table>
<thead>
<tr>
<th></th>
<th>Percent change from baseline to 12 month</th>
<th>Percent change from baseline to 24 month</th>
<th>Percent change from 12 month to 24 month</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Femoral neck BMD</strong></td>
<td>-0.191</td>
<td>0.353**</td>
<td>0.377**</td>
</tr>
<tr>
<td></td>
<td>-0.485</td>
<td>-0.147</td>
<td>0.143</td>
</tr>
<tr>
<td><strong>Wards BMD</strong></td>
<td>0.437</td>
<td>0.384**</td>
<td>0.241</td>
</tr>
<tr>
<td></td>
<td>-0.456</td>
<td>-0.560</td>
<td>0.028</td>
</tr>
<tr>
<td><strong>Trochanter BMD</strong></td>
<td>0.379</td>
<td>0.499**</td>
<td>0.420**</td>
</tr>
<tr>
<td></td>
<td>0.489</td>
<td>-0.057</td>
<td>0.124</td>
</tr>
<tr>
<td><strong>Total hip BMD</strong></td>
<td>0.147</td>
<td>0.535**</td>
<td>0.471**</td>
</tr>
<tr>
<td></td>
<td>0.251</td>
<td>0.160</td>
<td>0.130</td>
</tr>
<tr>
<td><strong>Total Spine BMD</strong></td>
<td>-0.282</td>
<td>0.112</td>
<td>0.047</td>
</tr>
<tr>
<td></td>
<td>-0.287</td>
<td>-0.383</td>
<td>-0.091</td>
</tr>
</tbody>
</table>

* Significant correlation (p<0.01)
** Significant correlation (p<0.001)

7.5 Changes in weight and BMD by physical activity categorized

Changes in weight and BMD in the three categories of moderate and vigorous physical activity are shown in table 4. The changes in weight and BMD did not differ significantly across the categories of physical activity. No significant correlations were observed between continuously scored minutes of moderate and vigorous physical activity at baseline or 12 months and consecutive changes in weight or BMD (results not shown).
Table 4. Percent changes in weight and BMD by physical activity categories.

<table>
<thead>
<tr>
<th></th>
<th>Moderate and vigorous physical activity (categories)</th>
<th>Moderate and vigorous physical activity (categories)</th>
<th>Moderate and vigorous physical activity (categories)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male/Baseline</td>
<td>Female/Baseline</td>
<td>Male/12 month</td>
</tr>
<tr>
<td></td>
<td>cat 0  cat 1-149  cat 150+  cat 0  cat 1-149  cat 150+  cat 0  cat 1-149  cat 150+  cat 0  cat 1-149  cat 150+</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>Mean Change from baseline to 12 month (%)</td>
<td>-20.1 -28.1 -26.9 -29.4 -31.8 -30.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Change from Baseline to 24 month (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Change from 12 month to 24 month (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Femoral neck BMD</strong></td>
<td>Mean Change from baseline to 12 month (%)</td>
<td>-9.3 -0.3 -2.4 -8.4 -6.9 6.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Change from Baseline to 24 month (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Change from 12 month to 24 month (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Wards BMD</strong></td>
<td>Mean Change from baseline to 12 month (%)</td>
<td>-7.7 -6.3 -5.8 -9.6 -10.1 -8.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Change from Baseline to 24 month (%)</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Mean Change from 12 month to 24 month (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Trochanter BMD</strong></td>
<td>Mean Change from baseline to 12 month (%)</td>
<td>-3.1 -9.0 -6.8 -10.4 -10.5 -9.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Change from Baseline to 24 month (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Change from 12 month to 24 month (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total hip BMD</strong></td>
<td>Mean Change from baseline to 12 month (%)</td>
<td>-3.2 -6.5 -6.1 -9.5 -9.6 -8.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Change from Baseline to 24 month (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Change from 12 month to 24 month (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Spine BMD</strong></td>
<td>Mean Change from baseline to 12 month (%)</td>
<td>-4.8 -7.1 -2.9 -5.2 -2.9 -4.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Change from Baseline to 24 month (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Change from 12 month to 24 month (%)</td>
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</tbody>
</table>
8 Discussion

The primary objective of this study was to assess if there was an association between physical activity and changes in weight and bone mineral density following bariatric surgery and to assess short-term weight loss and changes in BMD based on a 2-year cohort study. The findings do not support the idea that physical activity can attenuate bariatric-surgery induced bone loss. In line with previous studies, results shown significant weight loss during the first year after surgery in both women and men (Fleischer J. et al., 2008, Johnson J.M. et al., 2005), but during the second year the men gained weight by an average of 2.62 kg while the women kept losing weight. There was a significant loss in BMD during the first year at most measurement sites for men and at all measurement sites for women in current study. BMD kept decreasing at all measurement sites during the two years post-surgery in both women and men and was significantly correlated with weight loss in women. Our results are in agreement with some previous findings but not all. Fleischer J. et al. (2008) reported similar weight loss following bariatric surgery, or one third after one year of follow up time (approximately 30 kg whereas the mean value was 41 kg for men and 35 kg for women in our study). Fleischer et al. also found a decrease in total hip and femoral neck BMD, but did not find significant changes in total spine BMD. Both in the previous study by Fleischer et al. and in the current study a strong relationship was observed between weight loss and BMD loss (Fleischer J. et. al., 2008). Another study by Elaine W. Yu. et al. (2015) with two year follow up did report weight loss at the first year after the surgery, of similar size as in the current study or 39 kg in average, and there was a substantial bone loss throughout the 24 months after the surgery despite weight stability in the second year. Significant bone loss was observed at total hip and at trabecular spine, however there was no correlation between the weight loss and BMD loss at any site. Subjects were relatively fewer than in the current study, only 22 subjects and the analyses did not separate women and men (Elaine W.Y.U. et al., 2015). We did not observe any association between change in BMD and weight loss in the lumbar spine. Although our
sample was mostly young or middle age, this may perhaps be due to age-related degenerative changes in the spine (Tenne M. et al., 2012), leading to over-estimation of BMD at the lumbar spine.

Physical activity is known to attribute to many health benefits including a reduction in obesity-related complications (Puzziferri N. et al., 2014, Sjöström L., 2012, Stefater M.A. et al., 2012, Herpertz S. et al., 2003). In this study, number of minutes spent in moderate and vigorous physical activity per week decreased in both men and women from baseline to 12 months follow up and to 24 months follow up although the decline was not statistically significant. Mean number of minutes per week in moderate to vigorous activity decreased from 245.91 minutes per week to 66.22 minutes per week for men from baseline to 24 months follow up, and for women the decrease was from 141.02 minutes per week at baseline to 95.65 minutes per week at 24 months follow up. The World Health Organization’s recommendations for weight loss and prevention of weight regain for adults is to perform at least 150 minutes of moderate-intensity physical activity per week or at least 75 minutes of vigorous-intensity physical activity per week (World Health Organization, 2015). On average, both women and men were below these recommendations at 12 and 24 months follow up, but men did reach this recommended level at baseline. Changes in weight and BMD were not related to level of physical activity. One reason could be the low mean number of minutes of moderate-to-high intensity physical activity observed in both genders. These results are in line with those of a previous study with one year follow-up time where physical activity was not found to be associated with excess weight loss after bariatric surgery (Mundi M.S. et al., 2013). It can only be speculated if more minutes of physical activity (in particular meeting the recommended number of minutes) throughout the study period would have caused additional weight loss to the effect of the bariatric surgery. Yet it is interesting from a health behavior perspective to note that even with lower body weight and therefore an anticipated decrease in barriers to exercise (Colles S.L. et al., 2008), patients’ physical activity level decreased during the study period. The intensity of physical activity could also play a big role as other studies have shown that individuals who underwent bariatric surgery do more walking and low intensity physical activities rather than high intensity, which does not lead to increased weight loss after
the bariatric surgeries (Jakicic J.M. et al., 2008). One study (Bond D.S. et al., 2009) found that individuals who were inactive before surgery and remained active one year post-surgery, lost more weight than individuals who were inactive before and after surgery, those who became active also reported better overall physical health and mental health (Bond D.S. et al., 2009). In a second study by Herman et al., physical activity was not significantly associated with patients’ lowest weight reached post-surgery but associations were observed between moderate to vigorous physical activity, and weight loss in the long term while high sitting time was related to less weight loss among the patients, (Herman K.M. et al., 2014).

As we observed in the current study, Herman et al reported that subjects’ level of physical activity was much lower than the recommended level (Herman K.M. et al., 2014). Therefore, it seems necessary to focus on those who are inactive before surgery, decrease their sitting time and in particular to maintain or increase patients’ physical activity in post-surgery treatment to sustain the weight loss and maximize other positive health changes.

Physical activity did not attenuate BMD loss in the current study. The low mean number of minutes in moderate to high intensity activity may at least partly explain this, although it is not clear what level of activity the patients would have to reach in order to overcome the mechanical effects of weight loss in addition to the possible nutritional effects of the surgery. To our best knowledge, no other studies have assessed the impact of physical activity on bone loss following gastric bypass surgery. Previous studies have indicated that mixed loading exercise programs, combining jogging with other low-impact loading activities reduced postmenopausal bone loss at the spine and hip, and also could be effective in preserving bone mass in elderly individuals. Also, programs that are mixed with high impact activity and high magnitude exercise seem to be effective (Martyn-St James M., Carroll S., 2008, Kohrt, W.M, Bloomfield, et al., 2004). High impact exercise may not be the preferred type of physical activity in the obese population but other options such as resistance training with high loads but low impact may be more appealing to this group. This emphasizes the need to individualize training programs in clinical cases such as those under study here.
The current study has several strengths. In particular, this is a prospective study and therefore it is not likely that misclassification of parameters at baseline has affected the results. Also the study has rather many participants or 70, 59 women and 11 men, only 9 participants (2 men and 7 women) dropped out after 24 months follow-up. A single radiologist performed all BMD measurements, minimizing risk of bias. Further, a standardized questionnaire was used to assess physical activity and to my knowledge this is the first prospective study to assess if physical activity may affect changes in weight and BMD following bariatric surgery.

The study has some limitations however, that may have affected the results, such as relatively few subjects, particularly few males, resulting in low statistical power. The use of questionnaires to measure physical activity has some limitations, such as difficulties in assessing low vs high impact activity in addition to a possible bias in self-reported activity. Obese individuals seem to have a tendency to overestimate their physical activity and also underestimate their sedentary behavior (Bond D.S. et al., 2010). Therefore it is possible that the estimated levels of physical activity in the study were too high. Individuals that plan to undergo RYGB must follow a preparation program and reach weight loss goals prior to the surgery. During this period, the patients are encouraged to participate in physical activity and therefore, physical activity levels at baseline may have been unusually high for some of the subjects. Although we classified physical activity in an attempt to sort out participants with higher intensity activities, it is uncertain if those activities were of high or low impact. Advances in new technologies and measurement methods, especially accelerometers, show promise for future surveillance of physical activity but their ability to measure intensity of activity may not meet all research requirements (Hallal P., Andersen L.B., et al., 2012). There are some limitations of using DXA measurement for obese subjects, one reason is that fat layering could cause error and decreases the reproducibility of DXA for BMD in spine and hip measurements. This also affects single-energy QCT BMD measurements, but the error is smaller (Elaine W.Y.U., et al., 2012). Both DXA and QCT measurements can be affected by changes in marrow adiposity, but it is currently unknown whether marrow adiposity changes after gastric bypass. If changes occur in marrow adiposity in obese subjects after the surgery they might influence the bone
density results from both methodologies. Therefore, there is no standard imaging technique for measuring BMD in obese subjects or during weight loss (Elaine W.Y.U., et al., 2014).

In the current study there was limited data on diet and intake of nutritional substances, and finally it is possible that some of the women may have entered menopause at some point during the follow up causing an increased rate of bone loss although most subjects were younger than the mean age at menopause (Kohrt, W.M, Bloomfield, et al., 2004), even at the two-year follow up. The statistical analyses used in the study are limited to regression models whereas repeated measures analyses would have given the opportunity to further account for within subjects’ correlation of the bone mineral density measures.

The results confirm that bone loss continues into the second year after the surgery in spite of attenuated weight loss. The findings that physical activity did not affect neither bone- or weight loss indicate that more research is needed to assess the role of physical activity in influencing BMD loss after bariatric surgeries. The practical implications of this study are that patients who undergo bariatric surgery need to do more physical activity and/or put more intensity to the exercise, not only to affect weight change and bone density but also to acquire other well-known health benefits of regular physical activity of moderate to high intensity. Future research should monitor patients’ physical activity more frequently and include objective measures. Studies including accelerometers and/or measures of fitness would be preferable. Another option would be to offer detailed exercise instructions and in that case it could be more relevant to use a randomized controlled study design.

In conclusion, long term weight loss was correlated with BMD loss following bariatric surgery even after weight loss attenuates. To our knowledge, this is first study on the potential role of physical activity in this process. Many questions have risen, in particular related to the recommended intensities of physical activity, how to best measure those and also how to motivate obese individuals in weight reduction programs to perform this kind of activity. Physical activity did not correlate with weight loss or BMD at any point after the surgeries, therefore further research is required to
find out what type and intensity of physical activity will be most effective in reducing loss of BMD and enhancing weight loss after bariatric surgery.
References


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Appendix A

Upplýst samþykki fyrir þátttöku í rannsókn á langtíma áhrifum hjáveituðgerða á maga og görnum á beinabúskap karla og kvenna

Undirskrift þátttakenda:
Ég staðfesti hér með undirskrifuð minni að ég hef lesið upplýsingarnar um rannsóknina sem mér voru afhentar, hef fengið tækifæri til að spyrja spurningum um rannsóknina og fengið fullnægandi svör og útskýringar á atribum sem mér voru óljós.

Ég hef af fúsum og frjálsum vilja ákveðið að taka þátt í rannsókninni. Mér er ljóst, að þó ég hafi skrifað undir þessa samstarfssyflýsingu, get ég stóðvað þátttöku mína hvenær sem er án útskýringa.

Mér hefur verið kynnt eðli og umfang þessarar vísindaranansóknar og ég er samþykkið (ur) þátttöku og skrifa því undir þessi tvö eintök:

Dagsetning og staður:

Undirskrift þátttakenda

Undirritun þess sem aflar samþykkins

Upplýst samþykki þetta er í tvíriti, þátttakandi heldur eftir einu eintaki, sá sem aflar samþykkin heldur eftir óðru eintaki.
Appendix B

ALÞJÓÐLEGUR SPURNINGALISTI UM HREYFINGU

Við höfum áhuga á að vita hvers konar hreyfingu fólk stundar í sínu daglega líf.
Spurningarnar snúast um þann tíma sem þú varst á hreyfingu síðastliðna 7
daga.
Vinsamlega svaraðu öllum spurningum sem eiga við þig jafnvel þótt þér
finnist þú hreyfa þig lítið yfirleitt. Hugsadu um þá hreyfingu sem þú færð í
vinnunni, við húsverk og garðvinnu, við að komast milli staða og þegar þú
átt frí og notar það til að hreyfa þig þér til hressingar, til að þjálfa þig eða
stunda íþróttir.

Hugsadu um alla þá erfiðu og miðlungs erfiðu hreyfingu sem þú stundaðir
síðastliðna 7 daga. Hreyfing telst vera erfið ef hún reynir mikið á mann og
andardrátturinn verður mun hraðari en venjulega (þú verður móð/ur).
Hreyfing er miðlungs erfið (í meðallagi erfið) þegar hún reynir í meðallagi
mikið á líkamann og andardrátturinn verður heldur hraðari en venjulega.

1. HLUTI: HREYFING Í VINNUNNI

Fyrstu spurningarnar eru um vinnuna. Hér eru meðtalin launuð vinna,
sveitastörf, sjálfboðavinna, námskeið og öll önnur ólaunuð vinna sem þú
vannst utan heimilis. Ekki á að telja með ólaunaða vinnu heima við eins og
vinnu heimilisstörf, vinna í garðinum, gera við ýmislegt og sinna
fjölskyldunni. Spurt er um það í 3. HLUTA.

1. Ert þú í launuðu starfi eða stundar ólaunaða vinnu utan
heimilis?

☐ Já

☐ Nei → Svaraðu næst 2. HLUTA:

FERDAMÁTI

Næstu spurningar eru um alla þá hreyfingu sem var hluti af launaðri eða
2. Hve marga daga af síðastliðnum 7 dögum tókstu þátt í erfiðri hreyfingu

eins og að lyfta þungu, grafa, byggja eða flytja búslóð í vinnunni?
Hugsaðu eingöngu um þá hreyfingu sem stóð yfir í að minnsta kosti 10 mínútur í einu.

___ daga í viku

☐ Engin erfið hreyfing í vinnunni → Svaraðu næst 4. spurningu

3. Hve mikinn tíma tók erfiða hreyfingin venjulega hvern þessara daga í vinnunni?

___ klukkustundir á dag
___ mínútur á dag


___ daga í viku

☐ Engin miðlungs áreynsla í vinnunni → Svaraðu næst 6. spurningu

5. Hve mikill tími fór venjulega í miðlungs áreynslu hvern þessara daga í vinnunni?

___ klukkustundir á dag
___ mínútur á dag

6. Hve marga daga af síðastliðum 7 dögum varstu á göngu í að
minnsta kosti 10 mínútur í eiu í vinnunni? Vinsamlega teldu göngu í eða úr vinnu ekki með.

___ daga í viku

☐ Engin ganga í vinnunni → Svaraðu næst 2. HLUTA:

FERDAMÁTI

7. Hve mikill tími för venjulega í göngu hvern þessara daga í vinnunni?

___ klukkustundir á dag
___ mínútur á dag

2. HLUTI: FERDAMÁTI

Hér er spurt um hvernig þú ferðast milli staða, til dæmis í og úr vinnu, í búðir, í bíó og svo framvegis.

8. Hve marga daga af síðastliðnum 7 dögum ferðaðist þú um í ökutæki eins og strætó, bíl eða rútu?

___ daga í viku

☐ ferðaðist ekkert í ökutæki → Svaraðu næst 10. spurningu

9. Hve mikill tími för venjulega í að ferðast hvern þessara daga í strætó, bíl eða annars konar ökutæki?

___ klukkustundir á dag
___ mínútur á dag

Hugsaðu nú eingöngu um hvort þú hefur hjólað eða gengið til að komast í og úr vinnu, til að útrétta eða til að komast milli staða.

10. Hve marga daga af síðastliðnum 7 dögum förstu hjólandi í að minnsta kosti 10 mínútur í eiu til að komast milli staða?

___ daga í viku
Svaraðu næst 12.

11. Hve mikill tími för venjulega hvern þessara daga í að hjóla milli staða?

____ klukkustundir á dag
____ mínútur á dag

12. Hve marga daga af síðastliðnum 7 dögum förstu gangandi í að minnsta kosti 10 mínútur í einu til að komast milli staða?

____ daga í viku

Svaraðu næst 3. HLUTA: VINNA VID HEIMILISSTÖRF, GERA VID HÚSID OG SINNA FJÖLSKYLDUNNI

13. Hve mikill tími för venjulega hvern þessara daga í að ganga milli staða?

____ klukkustundir á dag
____ mínútur á dag

3. HLUTI: VINNA VID HEIMILISSTÖRF, GERA VID HÚSID OG SINNA FJÖLSKYLDUNNI

Þessi hluti snýst um hreyfingu þína síðastliðna 7 daga inná heimilinu og kringum húsið eins og heimilisstörf, garðvinnu, vinnu á lóð, almennar viðgerðir og við að sinna fjölskyldunni.

14. Hugsauð eingöngu um þá hreyfingu sem tók að minnsta kosti 10 mínútur í einu. Hve marga daga af síðastliðnum 7 dögum stundaðir þú erfiða hreyfingu eins og að lyfta þungu, moka þungum snjó, hlaða grjóti eða grafa í garðinum eða á lóðinni?

____ daga í viku

Svaraðu næst 16. spurningu
15. Hve mikill tími fór venjulega í erfða hreyfingu hvern þessara daga í garðinum eða á lóðinni?

____ klukkustundir á dag
____ mínútur á dag

16. Hugsðu nú aftur eingöngu um þá hreyfingu sem tók að minnsta kosti 10 mínútur í einu. Hve marga daga af síðastliðum 7 dögum stundaðir þú miðlungs erfða hreyfingu eins og að bera eitthvað létt, sópa, þvo glugga og raka í garðinum eða á lóðinni?

____ daga í viku

☐ Engin miðlungs erfð hreyfing í garðinum eða á lóðinni ➔ Svaraðu næst 18. sp.

17. Hve mikill tími fór venjulega í miðlungs erfða hreyfingu hvern þessara daga í garðinum eða á lóðinni?

____ klukkustundir á dag
____ mínútur á dag

18. Hugsðu nú enn og aftur eingöngu um þá hreyfingu sem stóð yfir í að minnsta kosti 10 mínútur í einu. Hve marga daga af síðastliðum 7 dögum stundaðir þú miðlungs erfða hreyfingu t.d. við að bera eitthvað létt, þvo glugga, skúra gólfr og sópa inni á heimilinu?

____ daga í viku

☐ engin miðlungs erfð hreyfing inni á heimilinu ➔ Svaraðu næst 4.

HLUTA:
Hreyfing til hressingar, í íþróttum og í frístundum

19. Hve mikill tími fór venjulega hvern þessara daga í miðlungs erfða hreyfingu inni á heimilinu?

____ klukkustundir á dag
____ mínútur á dag

4. HLUTI: Hreyfing til hressingar, í íþróttum og í frístundum
Næstu spurningar eru um alla þá hreyfingu sem þú hefur stundað síðastliðna 7 daga beinlínis þér til hressingar eða í þróttum, til þjálfunar eða í tómstundum. Vinsamlega teldu ekki með neina hreyfingu sem þú hefur þegar nefnt.

20. Ef þú telur ekki með neina göngu sem þú hefur þegar nefnt, hve marga daga af síðastliðnum 7 dögum fórstu í göngu í að minnsta kosti 10 mínútur í einu í frístundunum?

_____ daga í viku

☐ gekk ekkert í frístundunum → Svaraðu næst 22. spurningu

21. Hve mikill tími fór venjulega hvern þessara daga í göngu í frístundunum?

_____ klukkustundir á dag
_____ mínútur á dag

22. Hugsauð eingöngu um þá hreyfingu sem tók að minnsta kosti 10 mínútur í einu. Hve marga daga af síðastliðnum 7 dögum tókstu þátt í erfiðri hreyfingu eins og t.d. í þolfimi, við að hlaupa, hjóla hratt eða synda hratt í frístundunum?

_____ daga í viku

☐ Engin erfið hreyfing í frístundunum → Svaraðu næst 24. spurningu

23. Hve mikill tími fór venjulega hvern þessara daga í erfiða hreyfingu í frístundunum?

_____ klukkustundir á dag
_____ mínútur á dag

24. Hugsauð nú aftur eingöngu um þá hreyfingu sem stóð yfir í að minnsta kosti 10 mínútur í einu. Hve marga daga af síðastliðnum 7 dögum tókstu þátt í miðlungs erfiðri hreyfingu eins og að hjóla á venjulegum hraða, synda á venjulegum hraða og spila golf í frístundunum?

_____ daga í viku

☐ Engin miðlungs erfið hreyfing í frítímanum → Svaraðu næst 5. spurningu

HLUTA: TÍMI
25. Hve mikill tími fór venjulega hvern þessara daga í m'iðlungs erfiða hreyfingu í frístundunum?

_____ klukkustundir á dag
_____ mínútur á dag

5. HLUTI: TÍMI SEM FER Í AD SITJA

Síðustu spurningarnar eru um þann tíma sem þú situr í vinnunni, heima, á námskeiðum og í frístundum. Hér getur talist með tími sem fer í að sitja við skrifborð, í heimsókn hjá vinum, að lesa og að sitja eða liggja við að horfa á sjónvarp. Teldu ekki með neinn tíma sem fer í að sitja í ökutæki og þú hefur þegar talið með.

26. Hve mikill tími fór venjulega í að sitja á vírkum degi á síðastliðnum 7 dögum?

_____ klukkustundir á dag
_____ mínútur á dag

27. Hve mikill tími fór venjulega í að sitja á laugardegi eða sunnudegi á síðastliðnum 7 dögum?

_____ klukkustundir á dag
_____ mínútur á dag

Hér endar spurningalistinn. Kærar þakkir fyrir þátttökuna.
Appendix C

Graphs showing individual changes in BMD for spine and femoral neck and weight by subjects’ age, categorized into three age groups:

Figure 3 - Changes in BMD for spine by subjects at age 24-35 years old
Figure 4 - Changes in BMD for spine by subjects at age 36-45 years old

Figure 5 - Changes in BMD for spine by subjects at age 47-65 years old
Figure 6 - Changes in BMD for femoral neck by subjects at age 24-35 years old

Figure 7 - Changes in BMD for femoral neck by subjects at age 36-45 years old
Figure 8 - Changes in BMD for femoral neck by subjects at age 46-65 years old
Figure 9 - Changes in weight by subjects at age 24-35 years old
Figure 10 - Changes in weight by subjects at age 36-45 years old
Figure 11 - Changes in weight by subjects at age 46-65 years old