CHARLES UNIVERSITY
FACULTY OF SOCIAL SCIENCES
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The pay-off of increased physical activity in the Czech Republic: A cost-benefit analysis of offering people financial incentives to alter their exercise behavior

Bachelor's thesis

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Declaration of Authorship

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Abstract

The main objective of this thesis is to determine whether financial incentive to increase exercise behavior are economically feasible in the Czech Republic. We therefore construct a cost-savings model that compares current physical activity levels in the Czech Republic with two hypothetical physical activity improvement scenarios to assess the potential healthcare savings of a more fit population. The model follows an epidemiological approach and estimates potential healthcare savings based on the association of physical inactivity with five major non-communicable diseases. We conclude that neither improvement scenario justifies the implementation of financial incentive, as their costs are likely to exceed their benefits. Nonetheless our estimates show that healthcare expenditures due to physical inactivity are substantial. In particular, those associated with diabetes.

Keywords	physical activity, public budget, healthcare expenditures

Title	The pay-off of increased physical activity in the Czech Republic: A cost-benefit analysis of offering people financial incentives to alter their exercise behavior

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Abstrakt

Hlavním cílem této práce je zjistit, zdali je v České republice ekonomicky možná finanční pobídka ke zvýšení pohybového chování. Představujeme zde proto model úspor nákladů, kterí porovnává současnou úroveň fyzické aktivity v České republice se dvěma hypotetickými scénáři zlepšení fyzické aktivity, abychom vyhodnotili potenciální úspory za zdravotní péčí u zdatnější populace. Model se zakládá na epidemiologickém přístupu a odhaduje potenciální úspory ve zdravotnictví na základě spojení fyzické nečinnosti s pěti hlavními nepřenosnými nemocemi. Došli jsme k závěru, že ani jeden scénář zlepšení neospravedlňuje implementaci finanční pobídky, protože jejich náklady pravděpodobně převýší jejich přínosy. Naše odhady však ukazují, že výdaje za zdravotní péči v důsledku fyzické nečinnosti jsou znavčné. Zejména ty, spojené s cukrovkou.

Klíèová slova fyzická aktivita, veřejný rozpočet, výdaje na zdravotnictví

Název práce Výplata zvýšené fyzické aktivity v České republice: Analýza nákladů a přínosů nabízení finančních pobídek lidem ke změně jejich pohybového chování

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Acronyms

CI Confidence Interval

IBA Incentive–Based Approach

LB Lower Bound

MET Metabolic Equivalent of Task

NCD Non–Communicable Disease

PA Physical Activity

LB Lower Bound

PAF Population–Attribuable Fraction

RCT Randomized Controlled Trial

RR Relative Risk

UB Upper Bound

Bachelor's Thesis Proposal

Author	Valentin Schnabl
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Proposed topic	The pay-off of increased physical activity in the Czech Republic: A cost-benefit analysis of offering people financial incentives to alter their exercise behavior

Research question Can we make people in the Czech Republic more active via offering them financial incentives to exercises and what effect will this have on Czech health care expenditures?

Motivation In 2018 a report from the European Commission in cooperation with the WHO points out that in the Czech Republic only about 67% of adults and less than 30% of the under 18 population reach the level of physical exercise that is considered to be sufficient for maintaining a healthy lifestyle. (EC & WHO 2020) At the same time health care expenditures were estimated at 7.4% of the total Czech GDP. In comparison, national expenditures for education and sports were estimated at 4.5% and 0.4% respectively. However, these findings are not exclusive for the Czech Republic. Worldwide, 1 out of 4 adults does not reach the minimum level of physical exercise and the resulting sedentary lifestyle is a major driver of disabilities and premature death, with an approximated 2 million people dying each year from disease that can be traced back to insufficient physical exercise. (WHO 2018) In an attempt to reduce costs arising from diseases the WHO has already recommended a shift of attention away from treatments of sick, towards a promotion of health enhancing activities (WHO 2005). Particularly engaging people in more physical activity is of great importance as it is considered to be an effective preventative measure for a great variety of health risks factors. (Harvard Medical School, 2019)

Theory from behavioral economics suggests that one reason why people might not exercise enough is that an individualâ€™s â€śbenefitsâ€ť from exercising (e.g. lower body weight or increased fitness) take time to surface while on the other hand the costs of committing to a more active lifestyle have to be faced immediately. Moreover, these costs are said to be particularly high in the beginning of a personâ€™s transitioning phase (e.g. soreness, change of diets/habits). (Rothman n.d.) As people tend to respond more intensely to immediate benefits/costs than to benefits/costs that occur in future this can lead to an overestimation of the â€ścosts of exercisingâ€ť and an underestimation of its â€śbenefitsâ€ť (Herrnstein 1997). Offering people financial awards directly after completing an exercise task is thought to provide a solution to this cost-benefit mismatch problem that seems to be a driver of physical inactivity. This is also supported by research on the effects of financial incentives-based approaches (IBAs) on exercising behavior which provide evidence of increased levels of physical activity of observations after introducing financial awards for achieving activity targets. (Finkelstein, et al. 2008, Oâ€™Malley et al. (2012), Hafner et al. (2019) This thesis is about creating a model that showcases how increased physical activity levels in different age groups of the Czech population can translate into reduced health care expenditures. Moreover, onto the model we want to apply findings from research on the effect of different financial IBAs and compare results for different "improvement" scenarios and finally conduct a Cost-Benefit Analysis by comparing reduced health care expenditures with the investment required of running the different IBA programs.

Contribution On one hand, there exists research on the effectiveness of financial IBAâ€™s and on the other hand there exist work on the quantification of the economic costs of inactivity. However, combining these two research areas in order to conduct an analysis and a CBA in the specific setting of the Czech Republic has not been researched yet.

Methodology To analyze the effect of an increase of physical activity levels and the resulting decrease in healthcare expenditures, we first set up distribution of prevailing physical activity levels for the different age cohorts in the Czech Republic by utilizing data on self-reported weekly physical activity of Czech residence from a survey conducted by the European Commission. To calculate the changes in relative risk of suffering from diseases linked to insufficient exercise we employ global risk estimates of suffering from diseases given certain levels of exercise provided by the Global Burden of Disease (GBD). Using the physical activity distributions and relative risk estimates, we can calculate the overall relative risk by age group and the improvement, in terms of relative risk change, as a result of doing additional physical activity. The main focus in terms of diseases will lie on breast cancer, colon and rectum cancer, diabetes mellitus type 2, ischemic heart disease and ischemic stroke, as their link to sedentary lifestyle is well documented. (Hafner, et al., 2019). To arrive at the aggregate health care costs that can theoretically be saved, we then use data on health care expenditures per disease in the Czech Republic similar to Luengo-Fernandez, et al., 2013, and combine these with data on the prevalence of disease (GBD). Finally, we compare the outcome with the investment needed to run the financial IBA programs, also talking into account scenarios where there might be a shared interest of government and corporations to run a program that increases physical activity of participants.

Outline

1. Introduction
2. Literature review: Physical activity and its health benefits, why we do not exercise enough, Studies on the effect of financial IBAs
3. Methodology: Data sources, independent/dependent variables, The model and weaknesses of the model
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5. Conclusion

List of academic literature

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Author Supervisor

Chapter 1

Introduction

Researchers have recognized physical inactivity as a global pandemic (Kohl *et al.* 2012). Although the world does not need another pandemic it has been shown repeatedly that large parts of the world's population do not exercise enough. In response, the WHO has called for action and has issued minimum physical activity (PA) targets[1] that are necessary for maintaining a healthy weight and reducing the risks of many non-communicable diseases (NCDs) (WHO, 2020). However, about 23% of adult men and 32% of adult women fall below this minimum threshold, despite the devastating health consequences. The WHO (2020) estimates that diseases connected to insufficient physical activity are responsible for 5 million deaths each year. Guthold *et al.* (2018) claim that about one third of the adult Czech population does not reach the minimum PA target and therefore is exposed to increased risks of suffering from NCDs. Ding *et al.* (2016) estimate that about 4% of ischemic heart disease, 4.5% of ischemic stroke, 4.9% of diabetes mellitus type 2, 6.5% of breast cancer and 7.0% of colon cancer cases can be attributed to physical inactivity in the Czech Republic.

One reason why the importance of PA is often undervalued is the "present bias" which suggests that people are more responsive to immediate costs/benefits compared to future costs/benefits (Chakraborty 2021). In other words, since exercising demands a large initial effort, but reveals its (health) reward only much later, people might tend to forgo exercising to pursue something that offers immediate rewards (Loewenstein *et al.* 2007). Therefore, interventions

[1]The targets are similar for all adult age groups and lie around 150 minutes of moderate-intensity aerobic training or 75 minutes of vigorous intensity training or an equivalent combination of the two (WHO 2020)

that offer financial incentives to increase the present value of healthy behavior are common in healthcare settings. I.e., there exist so called conditional cash transfers (CCT's) in the US, that award money to households when they meet certain health criteria (like attending health care appointments). There also exist a variety of employer-sponsored financial incentive programs that reward demonstration of healthy behavior, including PA (Meredith *et al.* 2014). A growing literature is now concerned with ways of implementing financial incentive-based approaches (IBAs) to increase PA, and they report successes (Mitchell *et al.* 2013). Financial IBAs could therefore be a potential way for governments to increase PA in their societies and consequently reduce mortality and healthcare costs connected to major NCDs. This is an attractive prospect considering that healthcare expenditures in Czechia and across the globe are on the rise (OECD 2022) and that for the most part they are covered by public budgets (Ding *et al.* 2016). However, in an era with increasingly tight budgets (Ding *et al.* 2016), whether financial IBAs that reward PA are implemented will depend on their cost-effectiveness.

In this work, we approximate potential direct healthcare savings from increased PA using an epidemiologic approach introduced by Ding *et al.* (2016), by assessing the risk of five major NCDs. These diseases are, ischemic heart disease, ischemic stroke, diabetes mellitus type 2, breast cancer and colon cancer. Like Hafner *et al.* (2019) we update the approach to be able to compare current healthcare expenditures with expenditures of hypothetical PA improvement scenarios and project them 30 years ahead. The resulting cost-savings model (CSM) considers that PA developments can occur gradually and it incorporates demographic changes in Czechia. Finally with the results, together with literature on the effectiveness of financial IBAs, inferences about feasibility of each scenario will be made.

Chapter 2

Literature Review

The following text is an overview of scientific research that serves as a foundation for the CSM. It starts with an introductory section on current PA levels and afterwards is split into three parts. The first part is dedicated to the negative health consequences of insufficient PA. The second part deals with measuring the cost of insufficient PA using mainly epidemiological tools and the third part contains a summary of the efficiency of financial IBAs to increase PA.

2.1 Current physical activity levels

In 2018 Guthold et al. (2018) estimated the average global prevalence of physical inactivity for both sexes at 27.5% (95%CI 25.0–32.2) with high-income western countries performing worst, with an average inactive population of 42.3% (95%CI 39.1–45.4). Guthold et al. (2018) also claim that while physical inactivity is widespread but stable in high-income countries, it is rising in low-income countries. This development is largely attributed to the increase in sedentary occupations and motorized means of transportation when countries transfer from a low-income to high-income classification. Moreover, globally, there appears to be a consistent gap between men and women in terms of PA, with women generally exercising less (Guthold et al. 2018). Guthold et al. (2018) also estimated that in 2016 about 31.1% of the adult population in the Czech Republic did not reach the minimum PA target (28.1% of men and 33.9% of women).

2.2 The consequences of physical inactivity

Behavioral risk factors such as physical inactivity are amongst the leading causes of death and disability worldwide. This gets underlined by Moore *et al.* (2012) who report a stronglinear correlation between the life expectancy of adults aged 40+ and the amount of PA that they perform. For example, a physical activity level of 225[1] MET-minutes per week (between 75-90 minutes of walking) was connected to a 1.8-year increase in life expectancy (95%CI 1.6–2.0) as compared to individuals who were performing no PA at all. For individuals that matched the minimum PA level as recommended by the WHO (around 600 MET-minutes per week), the additional life expectancy was 3.4 years (95%CI 3.2–3.6) and any additional PA was connected to still further, although diminishing increases of life expectancy (Moore *et al.* 2012).

Other studies have used an isotemporal substitution models (ISMs) to analyze the effects of replacing sedentary behavior with PA. The ISM is used to estimate behavioral changes by taking into consideration that days are finite. It can therefore estimate what happens if people replace sedentary time with an equivalent amount of PA, but it can also model the effect of replacing different PA intensities (Mekary *et al.* 2009). The results show that replacing sedentary behavior with exercise reduces mortality risk and that the reduction is proportional to the exercise intensity. More specifically, Schmid *et al.* (2016) find that replacing 30 mins of sedentary behavior with light intensity PA leads to a decrease in premature mortality of 50% (95%CI 0.32–0.80) while replacing light intensity PA with moderate to vigorous PA further reduced mortality by 42% (95%CI 0.36–0.93). This correlation seems to be valid among all ages, sexes and ethnicities. One reason why insufficient PA can lead to premature death is that it represents a major risk factor for NCDs development.

Lee *et al.* (2012) estimated using a population attributable fraction (PAF) the effect of insufficient PA on the development of NCDs, finding out that globally around 6% of coronary heart disease (95%CI 3,9–9.6), 7% of type 2 diabetes (95%CI 5.6–14.1), and 10% of colon as well as breast cancer (95%CI 5.7–13.8) can be attributed to physical inactivity. In the Czech Republic esti-

[1]One MET corresponds to the amount of energy that is used by a person to perform a specific task relative to their body weight. For example, on average walking requires 2.5 METs, jogging 7 METs and rope jumping 11 METs (Ainsworth *et al.* 2000). MET-minutes are simply the product of MET*minutes for a given task. They are helpful because the WHO and other health organizations provide their PA recommendations in MET-minutes per week (WHO 2020)

mates by Ding et al. (2016) using a similar approach suggest that about 4% (95%CI 1.5–6.7) of ischemic heart disease, 4.5% (95%CI 2.2–7.1) of ischemic stroke, 4.9% (95%CI 2.4–7.7) of diabetes mellitus type 2, 6.5% (95%CI 2.5–10.6) of breast cancer and 7.0% (95%CI 3.6–10-7) of colon cancer cases can be attributed to physical inactivity. However physical inactivity does not only affect the development of these five NCDs. It has also been connected to an increased risks of suffering from high blood pressure and depression. Moreover, it has a detrimental effect on bone health, functional health, cognitive function, cardiovascular and muscular fitness, and it can lead to an overall unhealthier body composition (Lee *et al.* 2012).

It is worth mentioning that insufficient PA and a sedentary lifestyle are two distinct risk factors that can affect health outcomes independently. For example, Chau *et al.* (2013) find evidence for a correlation between time spent sitting and all-cause mortality. But they also find that PA can only partially offset this effect. Therefore, physically active individuals can still suffer from bad health consequences of a sedentary lifestyle if for example, their PA is limited to a few vigorous exercise spurts and the remainder of their day is spent sedentary. Sedentary behavior is generally characterized as an activity in a sitting, reclining or lying position (not sleeping) where 1.5 METs or less are expended (PAGAC 2018). There is no concern regarding this distinction for the construction of the CSM unless we believe that an increase in PA simultaneously promotes a more sedentary behavior. We address this issue by assuming, consistent with Hafner et al. (2019) that the additional time spend on PA is deducted from sedentary or other non-health promoting activities.

2.3 Research on the cost of physical inactivity

Research on the cost of insufficient PA can be done using an epidemiological or an econometric approach. The former usually requires estimating the disease-specific healthcare costs and then applying population attributable fractions (PAFs) (Ding et al. 2016). Where the PAFs can be interpreted as the proportion of each disease (or mortality) that would not exist if the risk factor, physical inactivity is eliminated (Hafner et al. 2019). Epidemiological approaches generally tend to produce lower estimates than studies using an econometric approach. This is likely because the epidemiologic approach usually only focus on a narrow set of diseases Ding *et al.* (2016). However, the econometric approach requires more comprehensive data on the individual level (Ding et al. 2016). As there is limited public data on individual healthcare expenditures and conditions, this paper follows the epidemiological approach, acknowledging its shortcomings.

This thesis was largely inspired by Ding et al. (2016) who compute the direct healthcare costs, indirect healthcare costs (productivity losses) and disability-adjusted life years (DALYs) attributable to physical inactivity for 146 countries, including the Czech Republic. For direct health-care costs and DALYs they use an epidemiological approach and estimate the PAFs for ischemic heart disease, ischemic stroke, type 2 diabetes, breast cancer and colon cancer. They estimate that in the Czech Republic insufficient PA was responsible for direct healthcare costs of 129 million Int$ (95%CI 41–322) and in the United States (US) it was 25,6 billion int$. In comparison, Carlson *et al.* (2015) using an econometric approach find that insufficient PA was responsible for healthcare expenditures of 117 billion USD in the US. The gap between these estimates is likely to stem from the fact that in the epidemiolocal approach only 5, out of at least 22 diseases that are connected to insufficient PA, are accounted for (Ding et al. 2016). Nonetheless Ding et al. (2016, p.1323) conclude that *"physical inactivity is a global pandemic that causes not only morbidity and mortality, but also a major economic burden worldwide."*

Further inspiration for this thesis was obtained from Hafner et al. (2019), who also used direct healthcare costs and PAFs connected to the above stated diseases to compute healthcare cost-saving. However, unlike Ding et al. (2016) who estimated total costs connected to physical inactivity, Hafner et al. (2019) estimated costs based on three PA improvement scenarios which they also projected 30–years ahead. So instead of accounting for the whole economic burden connected to physical inactivity, they looked at the share that can be eliminated under certain conditions. In scenario 1 they assume that everyone in the population reaches at least 600 MET-minutes per week with those already reaching this level being constant. In scenario 2, PA levels shift up by 20% for people who were already active before while the inactive remain constant; and scenario 3 is the combination of 1 and 2, where everyone engages in at least 600 MET–minutes and already active people increase their MET-minutes by 20%. For each scenario Hafner et al. (2019) assume that the improvement takes place immediately and that it remains constant afterwards. Then they compare projected healthcare expenditures for all scenarios with those of the status quo scenario, that has unchanged PA levels. They estimate global healthcare savings in 2020 to be 8.7 billion USD under scenario 1, 5.7 billion USD under scenario 2 and 11 billion USD under scenario 3. They only include few central European countries in their report and the Czech Republic is not among them. However, they estimate that in 2020 possible savings for Austria amounted to 24.2, 32.4 and 55.1 million USD for scenarios 1, 2 and 3 respectively (Hafner et al. 2019).

2.4 The effectiveness of financial-incentive-based interventions

Interventions via incentives to increase healthy behavior are common in healthcare settings, be it for smoking cessation, medication adherence or increased physical activity (Meredith et al. 2014). As countries begin to enact incentive–based interventions to increase PA of the population, research on their effectiveness emerges. In their metanalysis Mitchell *et al.* (2013) examines the effect of financial incentives (FIs) and different FI design features on exercise behavior. They include 11 studies in their analysis and show that FIs in the short–term increase the amount of exercise of adults by 11.75% (95%CI 4.60–18.96, p <0.001). In addition, they find that all the interventions have a positive effect on the previously inactive adults, suggesting that this subpopulation is particularly sensitive to FIs. In terms of FI design features, they concluded that guaranteed incentives (as compared to incentives of chance i.e taking part in a lottery) as well as objective behavior assessment (as opposed to self-reporting exercise progression) are most effective (Mitchell *et al.* 2013).

A more comprehensive study examining the role of FI design features was done by Farooqui *et al.* (2014). They identified the most promising incentive designs by surveying a sample of 50+ Singaporeans on a set of ten hypothetical PA incentive programs. The programs varied in exercise duration, frequency, amount of reimbursement, type of reimbursement and enrollment fees. Each participant was given a choice between two out of ten hypothetical exercise programs and asked to pick the option they preferred. Their answers were used to construct a random–utility model (RUM) that translates responses into an overall likelihood of participants joining any of the ten hypothetical programs. One of their key findings is that even modest financial incentives are expected to increase participation rates. Their model also suggests that enrollment fees do not deter participation, at least not in the range of 20 to 50 USD. They therefore conclude that entry–fees could be a potential way of lowering costs of running PA programs. In addition, if participants see them as form of deposit, they can also work as an extra incentive. A third major finding is that supermarket vouchers and cash incentives have similar effects on hypothetical enrollments and that they are more effective than sporting goods discounts (Farooqui *et al.* 2014).

Another incentive design feature was examined by Pope & Harvey-Berino (2013) who tested the effect of escalating FIs on PA. They conducted a randomized controlled trial (RCT) with university students and measured their gym attendance. FIs were structured such that rewards increased whenever participants were able to fulfill their PA targets. On the other hand, if participants failed to meet their target, the rewards were reset to the starting amount. Both treatment and control groups were given identical exercise schedules. The study results show that on average, participants receiving incentives met their exercise goals 63% of the time while participants of the control group only managed 13% of the time ($p < 0.001$). They also find that this effect is weaker when the exercise schedule gets more demanding. However, a follow up study found that PA levels of treatment and control group were back to being identical after financial incentives ceased (Pope & Harvey–Berino 2013).

Finally, Finkelstein *et al.* (2008) examined the effect of modest financial incentives on PA via an RCT with 50+ sedentary adults during a 4-week time period. Their regression model shows that financial incentives led to an average increase of 16 aerobic minutes ($p < 0.01$) per day as compared to the control group. Their model also implies that college education and higher household income have negative effects on PA outcomes. The average incremental payment for a member in the treatment group was 17.50 USD per week which led to an average increased of 1.8–hour light–to–moderate intensity PA per week.

Chapter 3

Data

The aim of this chapter is to introduce all the data sources that were used to construct the cost-saving model CSM. For the construction of the CSM, we require data on (1) current PA levels, (2) relative risks (RRs) and prevalence for five NCDs, (3) treatment costs for five NCDs and (4) Czech demographic projections.

3.1 Current PA levels in the Czech Republic

The current level of PA serves as reference values for the baseline scenario and starting point for each improvement scenario. To estimate the PA levels, we use data from the special Eurobarometer (EB) 472 survey. It was conducted by the EU-Commission (2017) and covers the adult (15+) population of all EU member states. The Czech Republic is represented with 1.024 observations. Like many international questionnaires the survey considers PA at three different intensities: (1) walking, (2) moderate-intensity PA and (3) vigorous PA (Hafner et al. 2019). In addition, each participant was asked how often per week and how long on average they engaged in each PA category (EB 2017).

The survey data was used to calculate corresponding MET-minutes for each observation. Furthermore, The translation of PA into MET–minutes makes it possible to compare different PA intensity levels with one another in terms of their impact on health outcomes. Following the example of Hafner et al. (2019) we assume, walking is equivalent to 2.5 METs, moderate-intensity PA to 4 METs and vigorous PA to 10 METs. Subsequently the total MET–minutes are calculated as:

$$MET_i = \sum_c MET_c * T_{ic}$$

Where c = walking, medium intensity PA, high intensity PA and $i = 1, 2 \ldots 1024$ is the index for each observation in the sample. T_{ic} stands for the time people spend on each PA category. As time was reported in 30 min intervals, we considered the midpoint of each interval. Observations including NAs were omitted.

3.2 Estimating PA distributions for each age group

As we want to calculate PAFs for multiple age groups and diseases (described in section 4.1) we require age specific RRs and PA distributions. PA distributions were obtained from the EB 472 questionnaire. However, as it was difficult to generate statistically significant estimates on PA levels within all age groups with only 1024 observations, we pooled Czech data with data of Slovakia, Slovenia, Austria and Poland. The countries were selected based on physical location, similar historic developments, similar performance in terms of PA and most importantly they also must not be rejected by a one factorial ANOVA test. The one factorial ANOVA test is used to compare the means of three or more samples with one another. It is rejected when at least one of the sample means is significantly different from the others (Flandorfer 2019). Table 3.1 contains an overview of chosen countries. It also includes Hungary which was pre–selected but rejected by the ANOVA analysis.

Table 3.1: Resources data pooling

Country	GDP	%-Unactive	ANOVA p-value
Czech Republic	17,920	0.283 (0.269–0.297)	reference
Slovakia	15,660	0.308 (0.295–0.322)	1.00
Austria	36,820	0.280 (0.267–0.294)	0.99
Poland	13,480	0.333 (0.318–0.350)	0.99
Hungary	13,660	0.227 (0.215–0.241)	0.00007
Slovenia	21,260	0.294 (0.282–0.307)	1.00

Source: GDP per capita: EUROSTAT (2022), Unactive population EB 472 (2017).

Figure 3.1 summarizes the distribution of PA for age groups after pooling the data. We estimate prevalence of insufficient PA for the whole population (performing below 600 METs) as 30.0% (95%CI 29.1-30.9).

Figure 3.1: MET ditribution by age group

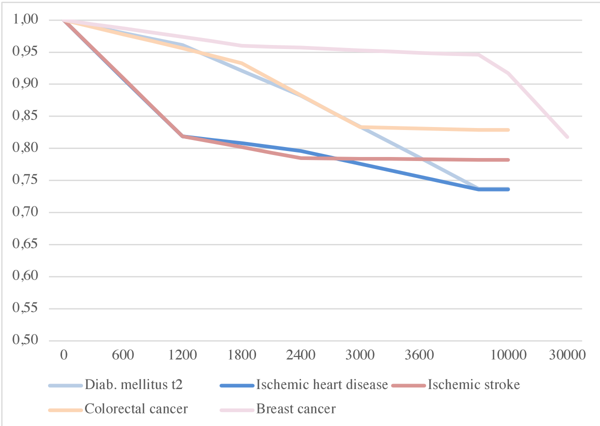
MET-minutes	15-24	24-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65+	All
0	1,9%	4,2%	4,5%	5,8%	7,2%	6,5%	8,4%	4,9%	4,0%	5,5%	5,4%
300	9,2%	11,1%	14,9%	14,5%	12,3%	13,0%	17,6%	16,3%	14,3%	16,9%	14,3%
600	8,9%	6,6%	8,9%	10,3%	10,2%	8,5%	12,3%	10,5%	8,4%	14,1%	10,3%
900	10,0%	8,3%	11,9%	6,5%	9,6%	10,8%	9,5%	11,6%	12,4%	14,0%	10,9%
1200	6,1%	8,0%	4,2%	7,1%	8,8%	7,5%	7,5%	7,6%	5,9%	7,1%	7,0%
1500	7,2%	8,3%	10,7%	7,7%	8,0%	6,8%	6,7%	5,8%	10,6%	7,1%	7,8%
1800	7,5%	5,6%	5,7%	3,5%	6,7%	7,3%	3,9%	4,1%	5,3%	4,3%	5,3%
2100	4,7%	6,6%	4,2%	8,1%	3,7%	4,3%	2,2%	2,9%	5,3%	5,0%	4,6%
2400	5,0%	4,5%	4,8%	3,9%	4,3%	4,3%	3,6%	5,2%	5,9%	2,4%	4,2%
2700	6,7%	3,5%	4,5%	5,2%	1,9%	3,8%	2,0%	3,5%	3,1%	2,9%	3,6%
3000	4,7%	3,5%	2,7%	3,5%	2,9%	3,8%	3,9%	3,5%	1,6%	2,2%	3,1%
3300	3,6%	3,1%	2,4%	2,6%	1,3%	3,0%	3,1%	2,6%	1,9%	0,7%	2,3%
3600	3,1%	2,8%	0,9%	2,3%	3,2%	3,3%	0,8%	2,0%	3,1%	1,7%	2,3%
3900	1,4%	1,7%	3,0%	1,9%	1,1%	1,5%	2,5%	3,2%	1,9%	1,2%	1,9%
4200	1,4%	2,8%	1,2%	0,6%	1,3%	2,0%	3,1%	1,7%	1,2%	1,1%	1,6%
10000	17,5%	13,5%	12,8%	13,9%	14,2%	11,5%	10,9%	10,2%	12,1%	11,8%	12,7%
30000	1,1%	5,9%	3,0%	2,6%	3,2%	2,5%	2,0%	4,4%	3,1%	2,1%	2,8%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

3.3 Relative Risks and prevalence of diseases

Consistent with Hafner et al. (2019) we extract the latest estimates (2019) of prevalence for ischemic stroke, ischemic heart disease, diabetes mellitus type 2, breast cancer and colorectal cancer from the Global Burden of Disease (GBD) results tool database (GBDb 2019). Furthermore, we discount prevalence of colon and rectum cancer by a factor of 0.73. This is done because the GBD reports prevalence of colon and rectum cancer jointly, however the literature only supports a link between physical inactivity and colon cancer (Ding et al. 2016). We adjust prevalence based on a study on cancer surveillance that estimated colon cancer to account for 73% of colorectal cancer cases in Europe (Allemani et al. 2009). Since ischemic heart disease and stroke are common complications of diabetes, we discount prevalence for both diseases to prevent double counting. Like Ding et al. (2016) we therefore calculate PAFs for diabetes using hazard ratios (HR) for ischemic heart disease (2.06; 95%CI 1.82–2.24) and ischemic stroke (2.56; 95%CI 2.15–3.05). We use HRs as proxies for RRs and diabetes prevalence as exposure (Pe). The resulting PAFs are discounted from the prevalence of ischemic heart disease and ischemic stroke.

We extract age adjusted RRs from the Global Burden of Disease study 2019 data Resources (GBDa 2019). This study was coordinated by the Institute for Health Metrics and Evaluation (IHME), and it contains RR estimates for physical inactivity for the five NCDs. Besides being differentiated by age, the RRs are also provided for multiple levels of PA. It must be noted however that RRs for breast and colorectal cancer are not age differentiated but available only for the population as a whole (GBDa 2019). Therefore, in these two cases we calculated PAFs with non-aged standardized RRs. Figure 3.1 shows non-age standardized RRs as a function of METs. Moreover, only RRs for breast cancer were reported for PA levels above 10000 METs. For all other RRs we therefore assumed no further risk reduction beyond PA level of 10000 METs.

Figure 3.2: RRs standardized



Source: GBD (2019)

3.4 Demographic data

To account for demographic changes, we use data on population development provided by the Czech Statistical Office (CSO). We use the “Střední variant" including migration for men and women to project healthcare expenditures from 2020 until 2050 (CSO 2022).

3.5 Cost per case estimates

The direct medical costs for treating each of the five NCDs are taken from Ding et al. (2016). When they computed direct healthcare costs of insufficient PA worldwide, they also created country specific estimates for treatment costs. The treatment costs for the Czech Republic can be seen in table 3.3. They are provided in Int$ prices for 2013 which we adjusted for a 7–year inflation, since

2020 serves as the starting point of our model. Inflation was set at 1,53% per anum or a total of 11,1% over the seven year time span (example of source).

Table 3.2: Cost per case estimates

Disease	Estimates 2013 Int$	Estimates 2020 Int$
Ischemic stroke	10,731.0	11,922.1
Ischemic heart disease	2,026.0	2,250.9
Diab. mellitus t2	2,334.0	2,593.1
Colon cancer	5,692.0	6,323.8
Breast cancer	2,220.0	2,466.4

Source: Ding et al. (2016)

Chapter 4

Methodology

The methodology for the CSM largely follows the examples of Hafner *et al.* (2019) who estimated potential healthcare savings for different PA improvement scenarios. Their work in turn was influenced by earlier contributions of Ding *et al.* (2016). Specifically, estimating the effect of insufficient PA via direct healthcare costs and PAFs of five major NCDs, was already estimated by Ding *et al.* (2016). Hafner *et al.* (2019) used their method but updated it, to fit their dynamic models. The following chapter provides in depth summary of their approach. What distinguishes this work however from Hafner *et al.* (2019), is that PA improvements are assumed to develop gradually instead of immediately. How the gradual increase in PA gets integrated in the model is explained in section 4.2.1 . The methodology section is divided into two main parts. The first part explains the calculation of PAFs while the second part deals with the CSM, for which the PAFs are an essential element.

4.1 Population attributable fraction (PAF)

The PAF is an epidemiologic measure that is used to assess the health impact of certain exposure on populations. It is defined as the fraction of all cases of a particular disease (condition) in a population that can be attributed to a specific exposure (Mansournia & Altman 2018). Suppose that O refers to the observed numbers of subjects with disease and E stands for the expected numbers of cases with diseases when the risk factor is eliminated, then for country j, we have:

$$PAF = \frac{O_j - E_j}{O_j}$$

Moreover, if we denote:

Table 4.1: Variables PAFs

	with disease	without disease	totals
Exposed group	a	b	X
Unexposed group	c	d	Y

Then we can rewrite the PAF as:

$$\frac{O_j - E_j}{O_j} = \frac{(a+c) - \left(X\frac{c}{Y} + c\right)}{a+c} = \frac{a - X\frac{c}{Y}}{a+c}$$

(Lin & Chen 2019)

There exist two commonly applied formulas to estimate PAFs in epidemiologic studies:

$$PAF = \frac{Pe * (RRcr - 1)}{1 + Pe * (RRcr - 1)} \tag{4.1}$$

$$PAF = P_C \frac{(RR_{adj} - 1)}{RR_{adj}} \tag{4.2}$$

Formula (4.1) is called Levin's formula and requires knowledge about the share of population that is exposed to certain risk factor: $Pe = \frac{X}{X+Y}$ as well as RRs unadjusted for confounders (crude RR). On the other hand, formula (4.2), or Miettinen's formula, requires the share of exposure amongst people that develop the disease: $Pc = \frac{a}{a+c}$. Moreover, RRs in Miettinen's formula are usually adjusted for confounding, hence they are denoted as RR_{adj}. (Lin & Chen 2019) Mathematically both formulas can be shown to be identical.

Considering that:

$$RR = \frac{\frac{a}{X}}{\frac{c}{Y}} = \frac{a * Y}{X * c}$$

Then for Levin'formula we have:

$$PAF = \frac{Pe * (RR - 1)}{1 + Pe * (RR - 1)} = \frac{\frac{X}{(X+Y)} * \frac{(aY - Xc)}{Xc}}{\frac{X}{(X+Y)} * \frac{(aY - Xc)}{Xc} + 1} = \frac{\frac{XaY - X^2c}{(X+Y)Xc}}{\frac{X(aY - Xc) + (X+Y)c}{(X+Y)c}} =$$

$$= \frac{X(aY - Xc)}{X(aY - Xc + Xc + Yc)} = \frac{aY - Xc}{aY + cY} = \frac{a - X\frac{c}{Y}}{a+c}$$

And for Miettinen's formula we have:

$$PAF = P_c * \frac{RR-1}{RR} = \frac{\left(\frac{a}{a+c}\right) * \left(\frac{aY-Xc}{Xc}\right)}{\frac{aY}{Xc}} = \frac{aY - Xc}{aY + cY} = \frac{a - X\frac{c}{Y}}{a+c}$$

(Lin & Chen 2019)

Weather researchers chose one or the other formula usually depends on the type of study they conduct. Levin's formula in commonly used in case-control studies while Miettinen's formula is used in cohort studies. The rationale behind this is that in case–control studies researchers do not have sufficient information regarding the exposure information among subjects without disease and thus Pe is unattainable (Lin & Chen 2019). In addition, Miettinen's formula is preferred when there is confounding as it still produces unbiased PAF estimates (Lee *et al.* 2012). Levin's, using unadjusted (crude) RRs on the other hand, provides unbiased PAFs only in the absence of confounding. (Lin Chen 2019). Possible confounding risk factors are i.e. hypertension in ischematic heart disease and overweight in diabetes, which are exacerbated by physical inactivity Lee *et al.* (2012). In our analysis we use Levin's formula because we only have access to RRs unadjusted for confounding. In addition, we also do not have information on $Pc\hat{A}\cdot$, that is we do not know the distribution of physical inactivity for people that end up getting the five NCDs. Ding *et al.* (2016) used both formulas and estimates for unadjusted/adjusted RRs to calculate PAFs for five NCDs. In their analysis Miettinen's formula produces lower PAFs for all five diseases. This suggests that the bias from using Levin's formula is likely to be upward. However, as Lee *et al.* (2012) point out, the PAFs from Levin's formula and unadjusted RRs might still work to provide perspective. Furthermore, what also distinguishes this work from that of Ding et al. (2016) is that we calculate PAFs using multiple levels of exposure and then sum them up to represent the total PAFs. This is possible due to the distributive property of PAFs (Rockhill *et al.* 1998). Formally for Levin's formula:

$$PAF_{a,d} = \frac{\sum_{m \in M} Pe_{m,a,d} * (RR_{m,a,d} - 1)}{1 + \sum_{m \in M} Pe_{m,a,d} * (RR_{m,a,d} - 1)}$$

And for Miettinen's:

$$PAF_{a,d} = \frac{\sum_{m \in M} P_{m,a,d} \, (RR_{m,a,d} - 1)}{\sum_{m \in M} RR_{m,a,d}}$$

Where m refers to the specific MET-interval of the whole interval $M = [0 - 30.000]$, d refers to the disease and a to the specific age group of all age groups A. The distributive property of the PAF has two implication that are relevant for our CSM. On the one hand side, a broader definition of exposure will always increase the PAF, provided that each additional level of exposure included has a $RR > 1$. On the other hand, a more inclusive definition of exposure might decrease precision, as standard errors of the PAF increase when more than 50% of the sample are exposed (Rockhill *et al.* 1998).

Given these properties, we must weigh up two conflicting arguments. On one hand, it is common practice to define exposure in a broad way (and non-exposure in a narrow way). I.e. Lim *et al.* (2012) define exposure to physical inactivity as everyone performing less than 8.000 MET-minutes per week. A broad definition of exposure also makes intuitive sense for our analysis considering that RRs are provided for MET-levels ranging from 0 up to 10.000 METs per week (even up to 30000 METs per week for breast cancer). Therefore, defining exposure to physical inactivity as everything below 30000 METs would ensure that the whole range of risk exposure levels are accounted for in the PAFs. On the other hand, researchers argue that when modifiable risk factors are used and the results should be relevant for public health decision, *"the exposure cut point should be chosen so that the unexposed level is realistically attainable by those in the exposed category"*(Rockhill *et al.* 1998, pg. 18). This approach leads to more conservative estimates but ensures that the results are more meaningful for public policy decisions (Rockhill *et al.* 1998). To account for this argument calculating PAFs in two ways. Once for an upper–bound scenario (UBS), where we apply a very broad definition of exposure (performing below 30.000 METs per week) and once for a lower-bound scenario (UBS), where exposure is defined as performing below 2.400 METs. Table â€¦ in the results sections summarizes the two versions of PAFs used.

4.2 Cost-savings model (CSM)

With estimates of PAFs consistent with HAfner et al. (2019) we can calculate the expected healthcare expenditures by age group, disease, and time as:

$$c_{a,d,t} = h_{d,t} * f_{a,d} * PAF_{a,d} * x_{a,t}$$

Where $h_{d,t}$ is the cost–of–treatment for each of the five diseases d at time t, $f_{d,a}$ is the prevalence in % for each disease and age group, $PAF_{d,a}$ is the population-attributable fraction for a particular age group a and disease d, and $x_{a,t}$ represents the share of population in each age group. The total expected healthcare costs per year can then be calculated as:

$$c_t = \sum_{a \in A} \sum_{d \in D} c_{a,d,t}$$

Values c_t for $t = 0, 1, 2 \ldots 30$ serve as our reference healthcare expenditures to which the improvement scenarios are compared to.

4.2.1 Physical activity improvement scenarios

We calculate healthcare savings for improvement scenarios by adjusting disease and age group specific healthcare expenditures $c_{a,d,t}$ with an adjustment factor that captures the reduction in RRs for increased levels of PA. Formally:

$$c^*_{a,d,t} = c_{a,d,t} * l^*_{a,d,t}$$

We arrive at $l^*_{a,d,t}$ via the following steps: First, for all MET intervals $m_i \epsilon M \mid m_1 = [0, 300)\,,\ \ m_2 = \ \ [300, 600)\,,\ \ldots m_{16} = [10000, 30000]$, where $i = 1,\ 2,\ \ldots 16$, and $M = [0 - 30.000]$ we assume that the share of population within each m_i is uniformly distributed. That is, $x_{m_i,a,t} \sim U(m_i)$. Then for each improvement scenario we can calculate p_{m_i} the proportion of people that moves onto a higher MET interval due to increased PA as:

$$p_{m_i} = \frac{I}{m_i^{\max} - m_i^{\min}}$$

Where I represents the MET improvement. I.e., a weakly PA increase of 45 MET–minutes in MET–interval m_1 translates into: $p_{m_1} = \frac{45}{300-0} = 15\%$. The 15 % in this example can be interpreted as the share of population that is ascending from a $[0 - 300)$ onto a $[300 - 600]$ MET–interval due to an weekly increase in PA. Equivalently there exist $p_{m_2},\ \ p_{m_3},\ \ \ldots\ p_{m_{16}}$. So generally, the population share by MET category age group and time $x_{m_i,a,t}$ can be calculated as:

$$x_{m_i,a,t} = \Big(x_{m_i,a,t-1} + p_{m_{i-1}} * x_{m_{i-1},a,t-1} - p_{m_i} * x_{m_i,a,t-1}\Big) * P_t$$

Where $x_{m_i,a,t-1}$ is the population share in MET–bracket m_i from the previous year. $p_{m_{i-1}} * x_{m_{i-1},a,t-1}$ and $p_{m_i} * \ x_{m_i,a,t-1}$ represent the share of people entering from a lower and ascending onto a higher MET–bracket respectively. P_t represents the population change factor and is a direct consequence of the Czech population projection data provided the CSO. In this way we can trace the population share in each age group and MET-category throughout the 30-year timeline. Note that for the baseline scenario we have that $p_{m_{i-1},a} = p_{m_i,a} = 0$.

For each improvement scenario we can calculate the share of the total population in each MET bracket as:

$$s_{m,a,t} = \frac{x_{m,a,t}}{\sum_a^A x_{m,a,t}}$$

Like Hafner et al. (2019) we then calculate RRs per age group and disease as a weighted sum of individual relative risk estimates with the population share serving as our weights:

$$rr^*_{a,d,t} = \sum_{m \in M} s^*_{m,a,t} * RR_{m,a,d}$$

For improvement scenarios and:

$$rr^0_{a,d,t} = \sum_{m \in M} s^0_{m,a,t} * RR_{m,a,d}$$

For the baseline scenario. Where $rr^*_{a,d,t} \leq \ rr^0_{a,d,t}$.

Then for all improvement scenarios we calculate the risk reduction relative to the baseline scenario and the minimum attainable RR for each disease:

$$l^*_{a,d,t} = 1 - \frac{rr^0_{a,d,t} - rr^*_{a,d,t}}{rr^0_{a,d,t} - \min\left(RR_{a,d}\right)}$$

Finally, we calculate healthcare expenditure savings for each of the PA improvement scenarios:

$$c^*_{a,d,t} = c_{a,d,t} * l^*_{a,d,t}$$

And total costs c_t^* and savings w_t^* as:

$$c_t^* = \sum_{a \in A} \sum_{d \in D} c_{a,d,t} * l_{a,d,t}^*$$

$$w_t^* = \sum_{a \in A} \sum_{d \in D} c_{a,d,t} * (1 - l_{a,d,t}^*)$$

It must be noted however that the model requires at least four simplifying assumptions. One of them regards the nature of distribution in MET–categories as discussed already. The remaining assumptions follow from Hafner et al. (2019). Firstly, physical improvements are permanent. Secondly, in our baseline scenario, PA levels remain constant and thirdly, individuals do not substitute the additional time spend performing PA with other health-enhancing activities. Moreover, all results are expressed in Int$, because it makes the comparison to similar works more convenient.

Chapter 5

Results and Discussion

In the penultimate chapter we first summarize results for PAFs and compare our own expected healthcare expenditures with results from Ding et al. (2016). Then we will discuss two types of improvement scenarios: (1) METs increase linearly and equally across the whole population and (2) the MET improvements are depended on how much PA people already perform. For each type of scenario there is an upper-bound and a lower-bound scenario. We will link the scenarios with the literature on effectiveness of financial IBAs. However, considering the limitations of studies assessing the effects of financial IBAs , any inferences must be handled with caution. A section on the strengths and limitations of the CSM will conclude this chapter.

5.1 PAFs and Healthcare costs connected to insufficient PA

Figure 5.1 provides an overview of PAFs results. Estimates for the less inclusive definitions of exposure are significantly lower than those of a more inclusive definition of exposure to physical inactivity. In particular, the estimates for diabetes and breast cancer in the LB case correspond to only a fraction of their UB counterparts. This is because the RRs of both diseases are slowly declining on the lower, but rapidly declining on the upper end of the MET distribution. This could suggest that large doses of PA are disproportionally effective in preventing diabetes mellitus type 2 and breast cancer as compared to smaller ones. For ischemic stroke it is the other way around. Suggesting that small increases in PA are already very effective in lowering risks. However, we must be very careful when interpreting the RRs estimates as they are likely subjected to confounding. I.e it has been shown that obesity is connected to increased risk of diabetes as well as lower rates of PA (Lee et al. 2012). Since people who are physically active usually have a lower BMI (PAGAC, 2018), this could very well confound the relationship of PA and the risk of suffering from diabetes type 2 in the direction that we are witnessing.

Figure 5.1: PAF estimates

Age group	Ischemic stroke		Ischemic heart disease		Diabetis mellitus t2		Colorectal cancer		Breast cancer	
	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
15-24	5,3%	5,6%	4,9%	10,3%	4,6%	16,7%	4,6%	9,8%	1,2%	14,7%
25-29	5,8%	6,1%	5,3%	10,7%	4,9%	16,8%	4,9%	10,1%	1,3%	14,3%
30-34	7,2%	7,5%	6,4%	12,1%	5,7%	18,3%	5,7%	11,2%	1,5%	15,0%
35-39	7,2%	7,5%	6,4%	12,0%	5,5%	18,1%	5,5%	10,9%	1,5%	14,9%
40-44	7,4%	7,7%	6,6%	12,2%	5,9%	18,3%	5,9%	11,4%	1,6%	14,9%
45-49	7,2%	7,5%	6,4%	12,0%	5,7%	18,3%	5,6%	11,1%	1,5%	15,0%
50-54	8,8%	9,1%	7,9%	13,6%	6,5%	19,2%	6,4%	11,9%	1,9%	15,4%
55-59	7,7%	7,9%	6,9%	12,5%	5,9%	18,4%	5,8%	11,3%	1,6%	15,0%
60-64	7,0%	7,3%	6,2%	11,9%	5,7%	18,4%	5,7%	11,3%	1,5%	14,9%
65 plus	8,6%	8,9%	7,7%	13,6%	6,4%	19,4%	6,6%	12,4%	1,9%	15,4%

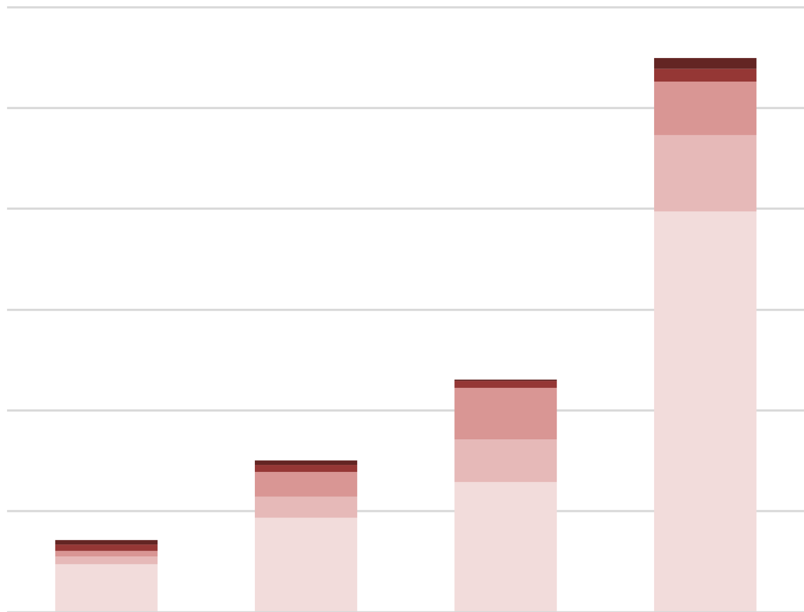
To put these estimates in perspective with the existing literature we refer to the results of Ding et al. (2016) and Lee et al. (2012) who estimated PAFs for NCDs using adjusted RRs with Miettinen's formula as well as unadjusted RRs with Levin's formula. Their results are summarized in figure 5.2. They gathered estimates for adjusted and unadjusted RRs from meta-regression analysis on the relationship between PA and all five NCDs. Their estimates are specific for the Czech Republic, however not standardized by age.

Figure 5.2: PAFs Ding et al. (2016) and Lee et al. (2012)

	Ding et al. (2016)		Lee et al. (2012)	
	Miettinen	Levin	Miettinen	Levin
Stroke	4,4%	9,1%	NA	NA
CHD	4,0%	7,3%	4,1%	7,6%
T2 diabetes	5,0%	13,0%	5,1%	13,6%
Colon cancer	7,0%	8,3%	7,4%	8,7%
Breast cancer	6,8%	7,8%	5,8%	7,1%

Our PAF estimates for the UB–scenario are much higher than those provided by Ding et al. (2016) and Lee et al. (2012) and naturally produce greater healthcare expenditure estimates. The estimates from the LB-scenario on the other hand are similar to PAFs obtained via Miettinen's formula (except for breast cancer). They also produce similar direct healthcare costs estimates as shown in figure 5.3.

Figure 5.3: Healthcare expenditures Ding et al. (2016) vs Own estimates



	Ding et al. (2016) adj. for π, 2013 prev.	Ding et al. (2016) adj for π and 2019 prev.	LB-Scenario	UB-Scenario
Breast cancer	8,0	8,9	2,5	22,2
Colon cancer	12,5	13,1	13,3	25,2
Stroke	11,6	49,9	102,5	106,0
CHD	15,5	41,1	85,1	151,4
T2 diabetes	94,8	187,3	257,5	794,6

We adjust Ding et al's (2016) estimates for inflation and 2019 disease prevalence according to the GBD data base. Then expected healthcare expenditures connected to insufficient physical activity are are 300.4 mill Int$ for Ding et al. (2016) and between 460.9 and 1,099.4 mill Int$ for LBS and UBS respectively. The difference between LBS and UBS are explained mainly by larger PAFs for diabetes in the UBS. The comparatively large share of diabetes mellitus type 2 on overall health expenditures is due to its high prevalence estimates. The GBD projects that there exist around 1.6 million cases (95%CI 1.4-1.8) of diabetes mellitus type 2 in the Czech Republic. In comparison, the GBD estimates that there are 508 K cases (95%CI 444-583) of ischemic heart disease, 105 K cases (95%CI 121-91) of ischemic stroke, 59 K cases (95%CI 74-48) of breast cancer and 33 K (95%CI 41-27) of colon cancer in the Czech Republic.

5.2 Scenario 1: constant increases of PA

In the first scenario we assume that PA increases steadily over 30 years and across the whole population. This approach implies that financial incentives are effective in increasing PA, regardless of how much PA a person already performs. One way that this improvement pattern might be feasible is the use of escalating financial incentives. Generally, for incentive-based treatment it has been shown that escalating incentive schedules can help to prolong periods of healthy behavior (Meredith *et al.* 2014). In addition, targeting behavior via performance improvements (as compared to performance standards) can be more effective in treating "hard-to-treat" patients (Meredith *et al.* 2014). We assume a yearly improvement of 50 MET–minutes per week. This translates into an increase of 20 minutes of extra walking (or any equivalent amount of PA) each weak.

Figure 5.4: Scenario 1: lower bound

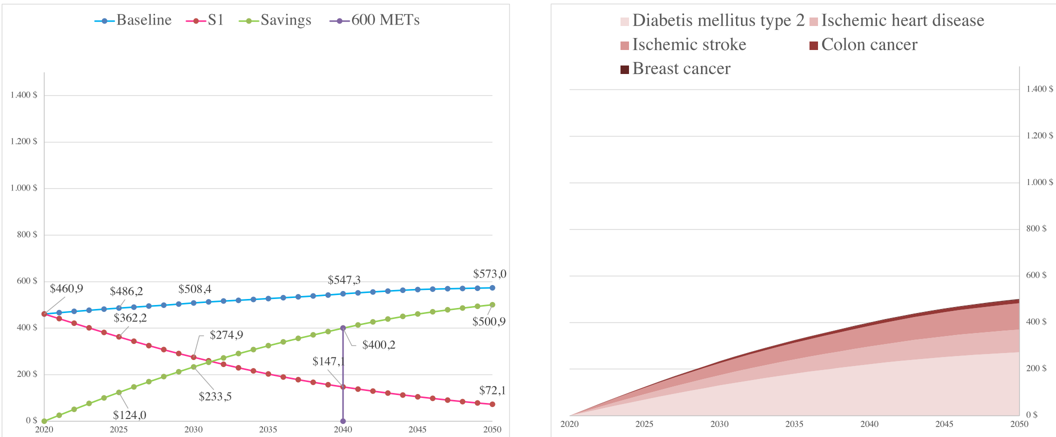
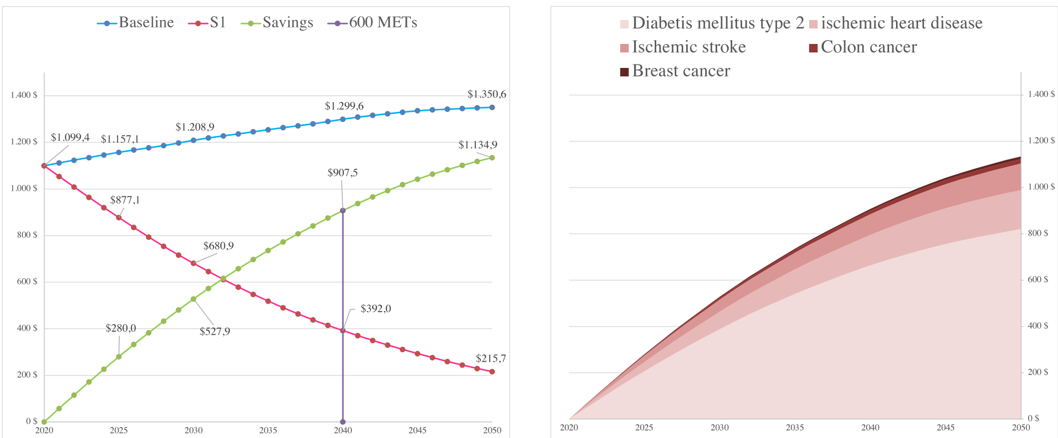


Figure 5.5: Scenario 1: upper bound



Under this scenario most healthcare expenditures due to PA are mitigated (pink line), most of which can be attributed to diabetes mellitus type 2. Moreover, it takes 20-years, for less than 1% of the population to be below the 600 MET–minute threshold (purple line). After approximately 13 years, half of healthcare expenditures due to increased PA are mitigated. In the lower bound scenario this development goes faster because here we assume that everyone above 2.400 METs is free from exposure. In other words, we are moving faster towards a more active society because there is a lower boundary for being “cured" from physical inactivity. However this improvement scenario entails a drastic and sustained behavioral change, that also needs to be financed. While escalating incentives structures can be used to sustain PA improvements over longer time periods, their effects become weaker as exercise schedules become more demanding (Pope & Harvey-Berino 2013). Moreover, people are expected to bounce back to their original PA levels as soon as incentives are withdrawn (Pope & Harvey-Berino 2013) and due to the exponential nature that such an incentive regime entails, it is likely that both government budgets and or personal constraints are getting in the way of implementing it. However, in terms of healthcare savings, after 5–years there would be a surplus of 124 mill Int$ in the lower bound and 280.0 mill Int$ surplus in the upper bound scenario. If we consider that Ding et al. (2016) estimated that 83.3% of healthcare expenditures in the Czech Republic are paid by the government then this translates to a 103.3 and 233.3 mill Int$ of additional government budgets for the two scenarios respectively after 5–years. If we equally spilt this budget amongst the whole adult population, we get that savings per person are 11.4 Int$ in the LBS and 25.7 Int$ in UBS. In comparison, Finkelstein et al. (2018) estimated that yearly payments of 910 $ (about 1092 $ in 2020) translated to PA increase of about 270 METs. This value is however significantly higher than the healthcare expenditure savings per person. Furthermore, this scenario implies that people's willingness to perform PA is mostly affected by the prospect of immediate rewards, however in reality other factors like i.e., infrastructure, social environment (Hafner et al. 2019), or physical constraints set boundaries to performing PA. Therefore, in the next scenario, we also consider the limits of financial incentives.

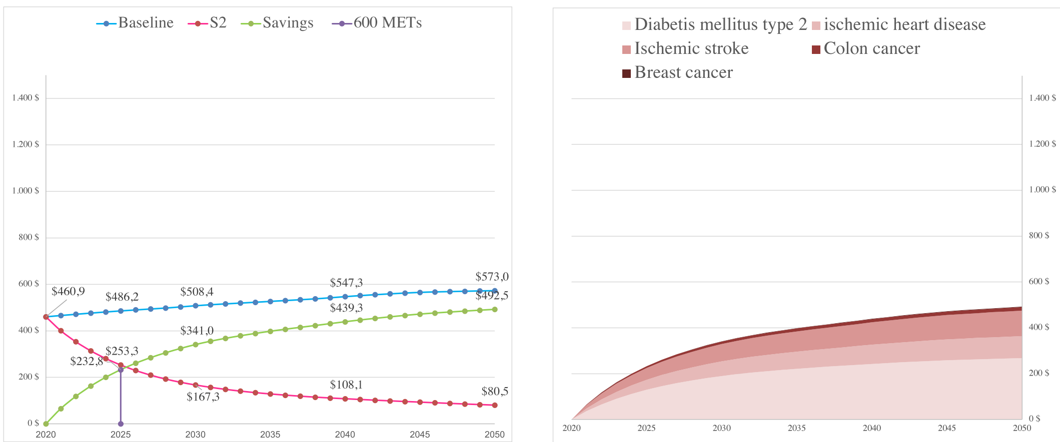
5.3 Scenario 2: Exponential increase of PA

For the second type of improvement scenario, we assume consistent with Finkelstein et al. (2008) and Mitchell et al. (2013) that financial incentives work well on previously inactive adults but that their effects wear off after people have reached a certain level of PA. We assume that financial incentives are most effective on the least active population and least effective on the most active population. This case is represented by a MET improvement I_{m_i} that is exponentially declining in MET-category. Formally:

$$I_{m_i} = y * v^{i-1}$$

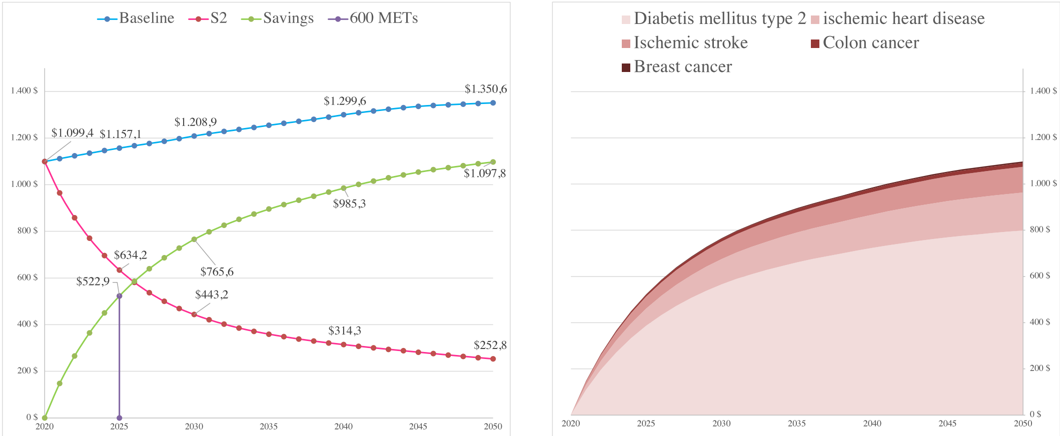
For MET category $m_i EM, i = 1, 2, \ldots 17$. The initial PA improvement y is equal to 270 METs, as this corresponds to the PA increase due to financial incentives reported by Finkelstein *et al.* (2008). The discount-factor v is assumed to be 0.63 as this was the performance decline reported by Pope & Harvey-Berino (2013) as exercise programs became more demanding. So, the MET improvement I_{m_i} gets almost halved each time people reach the subsequent MET interval and eventually wears off.

Figure 5.6: Scenario 2: lower bound



Under this scenario fewer healthcare expenditures are mitigated, over the course of the 30-year time horizon but more are mitigated in the short term. Direct healthcare expenditures due physical inactivity are halved within 5 to 6 years. Moreover, the 600 MET minimum target is surpassed already in 2025. Again, applying estimates of Ding et al. (2016) on the share of healthcare expenditures paid by the Czech government and splitting it up equally amongst the population we have that after 5-years, everyone contributed to healthcare

Figure 5.7: Scenario 2: upper bound



savings of 21.3 Int$, in the LB and 47.9 Int$, in the UB scenario. However, if we consider that only about 70% of the people in the sample are contributing to this change in healthcare expenditures, we might argue that only those are eligible for rewards. Then contributions of each "participant" would rise by 40%. If we also consider that epidemiological approaches generally produce conservative estimates compared to econometric approaches (Ding *et al.* 2016) and that governments could also impose enrollment fees (Farooqui *et al.* 2014) then we are moving closer to the required 1026 $ estimated by Finkelstein *et al.* (2008). However, we would have to make assumptions which are highly speculative given the existing literature. As it stands most RCTs assessing the effects of financial incentives are conducted on small sub-populations (Pope & Harvey-Berino 2013) Finkelstein *et al.* (2008), moreover the financial incentives used vary considerably among many dimensions Mitchell *et al.* (2013). On the other hand, focusing the attention of the public towards increasing PA levels of the previously inactive might prove to be more fruitful as compared to more general approaches. Nonetheless we conclude that, the costs of financial incentives to increase PA in the Czech Republic are likely to exceed their benefits.

5.4 Strengths and limitations of the model

5.4.1 Strengths

Like the model introduced by Hafner et al. (2019), the CSM accounts for age and MET category differentiated RRs and together with age-specific exposure rates, we can project direct healthcare expenditures related to insufficient PA specific to the Czech Republic. To attenuate this aspect, we incorporate data on demographics from the CSO. In terms of improvement scenarios, we assume that changes in PA happen gradually instead of immediately, as we belief it to be a better reflection of reality. Moreover, we estimate PAFs in two ways. Once by applying a broad definition of exposure and once whereby we chose a more realistic level of exposure as recommended by Rockhill, Newman and Weinberg (1998). The resulting UB and LB scenarios together with multiple variations for each scenario, provide additional perspective. Like Ding et al. (2016) and Lee et al. (2012) we only consider diseases that have a proven connection with physical inactivity. Moreover, the CSM also considers comorbidity of diseases.

5.4.2 Limitations

The estimates are solely based on five NCDs, however, there are at least 22 conditions that have a documented association with insufficient PA (Ding et al. 2016). In addition, the CSM does not consider indirect healthcare costs such as productivity losses due to absenteeism and presenteeism (reduced productivity at work due to ill health) or the economic costs of premature mortality. This contributes to an underestimation of costs connected to insufficient PA. I.e. Ding et al. (2016) estimate that indirect healthcare costs make up about 29% of total healthcare costs connected to insufficient PA in the Czech Republic. Moreover, the CSM also does not consider disability adjusted life years (DALY's) connected to physical inactivity. Another potential problem is that current PA levels were estimated based on self-reported data, which tends to underestimate the prevalence of physical inactivity and consequently its economic costs Ding *et al.* (2016). Finally, the use Levin's formula with RRs unadjusted for confounding is likely to lead to biased estimates for PAFs (Lin Chen 2019). The comparison with Ding et al. (2016) suggests that the PAFs are likely biased upwards and that therefore the CSM is overestimating direct healthcare costs connected with insufficient PA.

Chapter 6

Conclusion

The objective of this thesis was to conduct a cost-benefit analysis on whether the Czech government should start paying people to be more physically active. The initial aim was to set a price tag to physical inactivity or more specifically its negative health consequences and then assess weather financial incentive would work sufficiently well in increasing PA to make up for their own costs. The first objective was achieved with an epidemiologic model that can project healthcare expenditures savings. The model showed that current financial expenditures connected to insufficient PA are between 460 million and 1.000 billion Int$, depending on the definition of exposure applied. However, estimating costs connected to insufficient PA was only one part. The second part, the assessment of efficiency and costs of financial incentive programs, proved more difficult. Most of the existing literature on the effectiveness of financial incentives is based on small-scale experiments, and therefore any inferences were connected to large degrees of speculation. Nonetheless the model was able to incorporate a few general aspects about the relationship between financial incentives and physical activity. For example, that the effectiveness of financial incentives is decreasing when exercise schedules become more demanding (Pope & Harvey-Berino 2013) and that financial incentives work well on previously inactive adults (Mitchell *et al.* 2013). The resulting physical improvement scenario estimates were however not high enough to match the estimated costs of financial incentive interventions. Under these circumstances we conclude that the Czech government should not pay its citizens to be more physically active. However, we can confirm that *"physical inactivity is a global pandemic that causes not only morbidity and mortality, but also a major economic burden worldwide."* Ding et al. (2016, p.1323)

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