Thesis

Effects of a school-based physical activity intervention on cardiovascular and metabolic health of primary school children

submitted by

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Graz, 15.09.2025

Declaration of Academic Integrity

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Graz, 15.09.2025 Samuel Siller m.p.

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Abstract

The recent rise in obesity rates and the widespread prevalence of cardiovascular diseases - both placing a heavy burden on healthcare systems - have prompted the search for evidence-based strategies to improve youth health outcomes. This doctoral thesis investigated the effects of an additional daily 45-minute session of physical activity, delivered through active learning, on the cardiovascular and metabolic health of primary school children.

We collected data from 485 Austrian children aged 6 to 11 years from three schools in Graz, assessing their baseline status and changes over time (2021–2023) in systolic blood pressure, endurance (measured by the Andersen running test), body mass index (BMI) and waist-to-height ratio.

The findings are concerning: 23.5% of the children were overweight and 14.1% obese. Significant differences between schools were observed, likely reflecting socioeconomic disparities within the same city. Daily active learning significantly improved running performance in both intervention schools ($p < 0.001$), though it did not eliminate the large initial differences in endurance capacity between schools at baseline (intervention school 1 102%, intervention school 2: 94%, control school: 82% of the Norwegian norm). Children at the control school showed a decline in endurance relative to the norm, underscoring the urgent need to reduce sedentary time in primary education.

Changes in systolic blood pressure associated with the intervention were affected by the presence of white coat hypertension during baseline measurements, complicating interpretation. Nevertheless, we confirmed that children exceeding the 90th BMI percentile exhibited significantly higher systolic blood pressure. Furthermore, 16.8% of children had a waist-to-height ratio above 0.5, and 1.3% fell into the high-risk category above 0.6, indicating a strong likelihood of abdominal adiposity - a condition associated with insulin resistance and future adverse health outcomes. Changes in BMI and waist-to-height ratio due to active learning were not statistically significant, suggesting that more comprehensive approaches - such as involving nutritionists and school medical staff to provide targeted support for children and families - may be necessary.

Numerous factors influencing children's cardiovascular and metabolic health, discussed in depth in this thesis, offer valuable directions for future research. The health benefits of evidence-based training methods led by specially trained physical education teachers - incorporating strength, endurance, and skill-based exercises - should not be underestimated. A cross-school approach to fitness tracking and preventive action is urgently recommended.

Zusammenfassung

Aktuelle Entwicklungen steigender Zahlen an Übergewicht und hohe Prävalenz von Herz-Kreislauf-Erkrankungen mit weitreichenden Auswirkungen auf das Gesundheitssystem lassen nach evidenzbasierten Methoden suchen, um die Gesundheit der Jugend positiv zu beeinflussen. In zwei Volksschulen wurden zusätzliche 45 Minuten Bewegung in Form von aktivem Lernen im regulären Lehrplan implementiert. Daten von 485 österreichischen Kindern im Alter von 6 bis 11 Jahren aus drei Schulen in Graz wurden gesammelt und der Ist-Zustand sowie die Veränderung des systolischen Blutdrucks, der Ausdauerleistung (gemessen mit dem Andersen-Lauftest), des Body-Mass-Index und der Waist-to-Height Ratio von 2021 bis 2023 analysiert.

Die Ergebnisse geben Anlass zur Sorge und bestätigen einen hohen Anteil an Übergewicht (23.5%) und Adipositas (14.1%) sowie überraschend große Unterschiede zwischen den Schulen, die unter anderem mit sozioökonomischen Unterschieden, auch innerhalb derselben Stadt, zusammenhängen. Das tägliche aktive Lernen wirkte sich in beiden Interventionsschulen positiv auf die Laufleistung aus ($p < 0.001$), konnte jedoch die großen Unterschiede zwischen den Schulen zu Beginn der Studie nicht ausgleichen (Interventionsschule 1 mit 102%, Interventionsschule 2 mit 94%, die Kontrollschule mit 82% der norwegischen Norm-Laufdistanz). Die Kinder der Kontrollschule zeigten eine abnehmende Ausdauerleistung, was die Notwendigkeit einer Reduzierung der sitzenden Tätigkeit in der Volksschule verdeutlicht. Die mit der Intervention verbundenen Veränderungen des systolischen Blutdrucks wurden bei den Ausgangswerten signifikant durch das Vorliegen einer Weißkittelhypertonie beeinflusst, was eindeutige Schlussfolgerungen erschwerte. Dennoch konnten wir bestätigen, dass Kinder, deren BMI über dem 90. Perzentil lag, einen signifikant höheren systolischen Blutdruck aufwiesen.

16.8 % der Kinder zeigten eine erhöhte Waist-to-Height Ratio von über 0.5, wobei sich 1.3% bereits in der Hochrisikokategorie mit einer Waist-to-Height Ratio von über 0.6 befanden. Dies deutet auf eine hohe Wahrscheinlichkeit von abdominaler Adipositas hin, eine Erkrankung, die mit Insulinresistenz und zukünftigen gesundheitlichen Beeinträchtigungen verbunden ist. Veränderungen des Body-Mass-Index und der Waist-to-Height Ratio durch das tägliche aktive Lernen waren nicht eindeutig signifikant, was darauf

hindeutet, dass umfassendere präventive Ansätze, etwa eine intensivere Unterstützung der Kinder und ihrer Familien durch Ernährungsberater*innen sowie Schulärzten*innen, erforderlich sein könnten.

Zahlreiche Faktoren, die die kardiovaskuläre und metabolische Gesundheit von Kindern beeinflussen wurden in dieser Arbeit ausführlich diskutiert und bieten Anhaltspunkte für zukünftige Forschung. Das Gesundheitspotenzial von evidenzbasierte Trainingsmethoden durch speziell ausgebildete Sportlehrer*innen, die frühzeitig Krafttraining, Ausdauertraining und Geschicklichkeitsübungen initiieren, optimalerweise mit schulübergreifendem Überblick und Daten zur Fitness von Kindern und Jugendlichen, sollte nicht vernachlässigt und die intensivierte Umsetzung präventiver Maßnahmen als dringend erforderlich angesehen werden.

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Abbreviations

AAP	American academy of pediatrics
ACTH	adrenocorticotropic hormone
ADMA	asymmetric dimethylarginine
ANOVA	analysis of variance
ATP	adenosine triphosphate
BMI	body mass index
BP	blood pressure
CART	cocaine- and amphetamine-regulated transcript
CHILD	cardiovascular health integrated lifestyle diet
CIM	carbohydrate-insulin model
COSI	childhood obesity surveillance initiative
CS	control school
CV	cardiovascular
DALY	disability adjusted life years
diasBP	diastolic blood pressure
DNA	deoxyribonucleic acid
EF	ejection fraction
FU1	follow-up 1
FU2	follow-up 2
GDP	gross domestic product
GIP	gastric inhibitory polypeptide
GLP-1	glucagon-like peptide 1
HDL	high-density lipoprotein
HR	heart rate
HR_{max}	peak heart rate
HTN	hypertension
IS1	intervention school 1
IS2	intervention school 2
LDL	low-density lipoprotein
MET	metabolic equivalent of task
mmHg	millimetre of mercury
MODY	maturity-onset diabetes of the young

mTOR	mechanistic Target of Rapamycin
MyHC	myosin heavy chain
NO	nitric oxide
NO_2	nitrogen dioxide
NPY/AgRP	neuropeptide Y/agouti-related peptide neurons
PA	physical activity
PBM	peak bone mass
PCSK9	proprotein convertase subtilisin/kexin type 9
PI	physical inactivity
PM2.5	fine particles
POMC	proopiomelanocortin
RAAS	renin-angiotensin-aldosterone system
RCT	randomized controlled trial
REM	rapid-eye movement
SB	sedentary behaviour
SD	standard deviation
SHS	second-hand smoke
SV	stroke volume
sysBP	systolic blood pressure
T2DM	type 2 diabetes mellitus
VEGF	vascular endothelial growth factor
VLDL	very low-density lipoprotein
VO2max	maximal oxygen consumption
WHO	World Health Organization
WHtR	waist-to-height ratio
YLL	years of life lost

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1. Introduction

Promoting health and reducing morbidity as primary objective, this thesis will focus on the impact of increased physical activity in elementary school on running performance, blood pressure (BP), body-mass-index (BMI) and waist-to-height ratio (WHtR). Insight is gained through measurements during the study "Happy Children" performed in international cooperation from 2021 until 2023, in search for ways to improve cardiovascular (CV) and metabolic health across Austria, Europe and beyond. After discussing risk factors and risk behaviour as potential confounders barely altered in the intervention but influencing children's health, a look on the latest epidemiology-data helps to objectify the extent of the current issue, a major impulse of why the study performed.

1.1. Epidemiology

In the year 2022 Statistik Austria published their annual health report (1). In Austria 81,892 children were born alive, and 93,332 people died, from which 34,3% were caused by CV-diseases. Figure 1 shows cause of death of male and female individuals, subcategorized by dictated aetiology. Also, the most common cause of acute inpatient stays, about 12.7% of all cases, were due to circulatory system diseases.

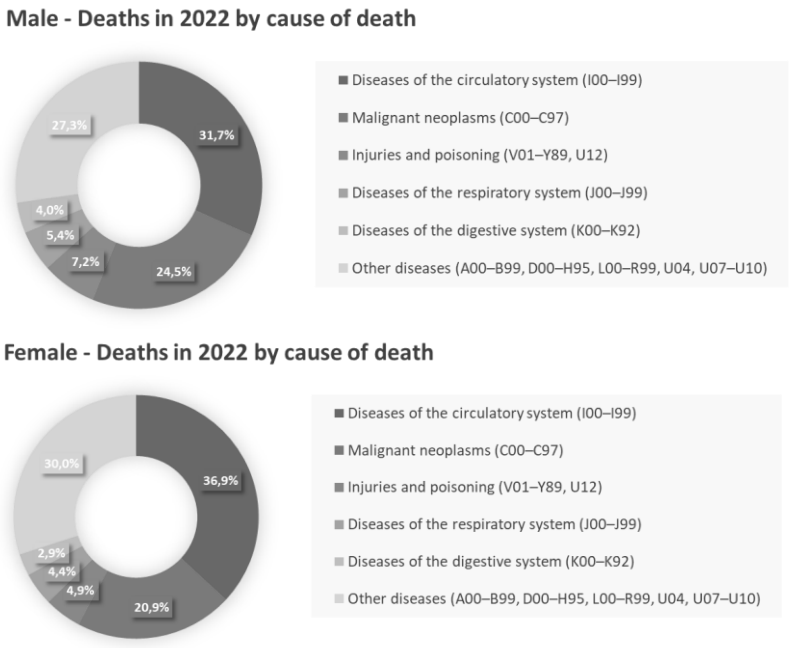


Figure 1 - Cause of death in Austria 2022

Source: Statistik Austria - Jahrbuch der Gesundheitsstatistik 2022 (1).

The high burden of circulatory disease is not just intertwined with years of life lost (YLL) and increased life years lived in ill-health or disability (DALY) but also leads to challenges for healthcare systems. Since 2004 Austrian healthcare expenditure has risen at an average annual growth rate of 4.3%, from EUR 23,531 million to EUR 49,897 million in the year 2022 – corresponding to 11.2% of gross domestic product (GDP). Further challenges can be expected due to demographic changes (aging society, declining birth rates, massive increase in single-person households), expensive technological innovations and increasing life expectancy. Rising prevalence of chronic diseases, for example diabetes and hypertension with resulting cardiovascular disease contribute to the rise in costs, which leaves us in search for solutions to reduce the number of people affected.

A major resource of promoting CV and metabolic health is starting early, optimally in childhood, encouraging physical activity (PA), therefore promoting fitness and reducing future rates of overweight and obesity. Challenges increased with digitalization, modern lifestyle and an abundance of calorie-dense and highly processed food, making it harder to counteract brain's innate preferences shaped by human evolution.

The health report provides a glimpse of the recent health state of young adults, data was gathered during Austrians annual military physical examination of 18-year-old male: During 2022s investigation a proportion of 11.9% of males were obese with a body mass index (BMI) of at least 30 kg/m^2, about a third (33.0%) were overweight with BMI between 25.0 and 30.0 kg/m^2. This makes it obvious that effective preventive strategies need to be found and applied to counteract status quo.

One of the biggest studies on childhood health was performed by the European Childhood Obesity Surveillance Initiative (COSI), initiated in 2007 by the World Health Organization (WHO) (2). With initial 13 countries participating, Austria joined COSI in Round 4 (2015-2017). From 5135 children invited, half of them participated in measurements, 1475 eight-year-old children had complete information gathered. Austria ranked 13^{th} for highest overweight prevalence (30.3% boys, 22.3% girls in 8-year-olds), 17^{th} for highest obesity prevalence (12.4% boys, 6.2% girls in 8-year-olds) from 38 countries.

Obesity is the result of a complex interplay of genetic and epigenetic factors, inherited biological predispositions, and the influence of sociocultural and environmental settings,

all of which disrupt the body's weight homeostasis. These mechanisms involve unconscious physiological processes, such as leptin and gastrointestinal feedback, as well as conscious ones, for example deliberate food choices or leisure activities (3).

Elevated blood pressure during childhood is a predictor of increased risk for developing hypertension in adulthood. In 2015 the prevalence of hypertension among 6-year-olds was 4.32% (95% CI, 2.79%-6.63%), notably higher in overweight and obese children. From 2000 to 2015 there was a significant upward trend with a relative increase around 76% in hypertension (HTN) prevalence. This rise is partially attributable to increasing rates of childhood obesity, with BMI remaining the strongest modifiable risk factor for hypertension in children (4).

1.2. Potential of Prevention

Primary prevention via health promotion is the most valuable approach to disease prevention. By focusing on the avoidance of risk factors, individuals can be protected from potentially irreversible negative health outcomes. Implementing PA across the curriculum helps to reach all children from different socioeconomic and cultural backgrounds, regardless of families engaging in preventive measures or not. It is a subtle way to positively influence children's long-term health, reducing later need for medical interventions. By fostering excitement for PA, children can develop healthy habits as a foundation in resilience and well-being throughout their lives. A Cochrane Review in 2017 examined interventions on diet, PA and behaviour as treatment of overweight or obese children from the age of 6 to 11 years. The review found that intervention groups showed a mean BMI reduction of 0.53 kg/m² and a mean weight reduction of 1.45 kg compared to control groups over a 36-month follow-up period (5). Despite these interventions, the observed changes in BMI and weight were modest, raising questions about their limited impact. Why are these changes miniature? Are there critical factors being overlooked, or is the challenge rooted in the complex interplay of multiple influences?

To achieve substantial and sustained improvements in childhood overweight and obesity, several key factors must be addressed. These factors are shortly discussed before examining the impact of our PA intervention in Austria. Long-term success likely requires a

holistic approach that integrates many elements to effectively support cardiovascular and metabolic health and maintain healthier lifestyles.

1.3. Physiology

With the "Happy Children" study an increase of exercise leads to changes and adaptations in children's heart, lungs, blood vessels, muscle tissue and bones. These short-term activities influence the body's energy metabolism, mitochondria, total energy expenditure and bodyweight homeostasis. Figure 2 presents an overview of influential factors of CV- and metabolic health, as well as aspects of health and fitness defined by ESC Guidelines of 2020 (6).

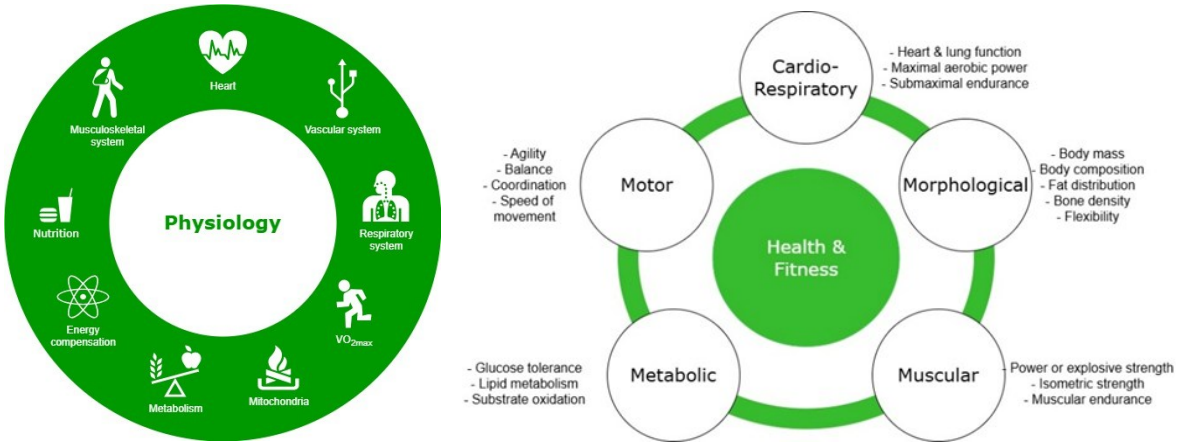


Figure 2 - Physiology of cardiovascular & metabolic health – Aspects of health & fitness

adapted from: 2020 ESC Guidelines on sports cardiology and exercise in patients with cardiovascular disease (6).

1.3.1. Heart

1.3.1.1. Cardiac Structure and Function

Cardiac muscle cells function as a syncytium, connected via gap junctions, contracting and relaxing in repetitive cycles, systole and diastole. These contractions are initiated by the sinoatrial node, the heart's natural pacemaker in the right atrium, which triggers a sequence through the atrioventricular node, bundle of His, bundle branches, and Purkinje network, all the way to the heart muscle cells. Blood then is pumped through heart valves, which open and close passively to maintain blood flow and pressure in the pulmonary and systemic circulation. The Windkessel effect of the elastic aorta smoothens the cardiac output into a more continuous flow, reducing strain on the heart (7).

1.3.1.2. Cardiac Regulation and Control Mechanisms

The cardiac output is influenced by heart rate (HR) and stroke volume (SV), leading to ejection fraction (EF), a measure of the hearts efficiency. Influences by the sympathetic and parasympathetic systems modulate HR via β-receptors, a release of noradrenaline and adrenaline increases HR and contractility, and vagal release of acetylcholine binding to muscarinic receptors decreases HR.

The Frank-Starling mechanism enables the heart to adjust pumping force based on venous return and helps balancing the right and left heart output. An increased pre-stretching of the myofilaments results in a higher contraction amplitude (8). Preload is related to ventricular filling, caused by central venous pressure and atrial contraction. Afterload is the work that is needed to eject the SV, mainly influenced by downstream blood pressure.

1.3.1.3. Blood Pressure and Circulation

In children it is common to specify percentiles and age norms for reference parameters. In September 2017 the American Academy of Pediatrics published reference values for blood pressure percentiles according to gender, age and height (9). The BP is regulated by cardiac output and peripheral resistance. BP drops as arteries branch throughout the body, with gradually shrinking diameter leading in countless arterioles, which provide most of total peripheral resistance. When measuring BP, one must consider that the BP physiologically follows a circadian rhythm, peaking in the afternoon and reaching its lowest during nighttime, defined as dipping (10). The high-pressure arterial system functions as a pressure reservoir, while the low-pressure venous system serves as a volume reservoir. BP and adapted blood flow to momentary needs is controlled by arteriolar resistance, with significant influences from endothelial function, vessel compliance and autonomic tone. Factors like nitric oxide (NO), prostacyclin, and myogenic tone play important roles in vascular regulation. During dynamic exercise, systolic BP rises continuously with increasing wattage, while diastolic BP drops slightly (11). This helps with blood flow efficiency and optimal oxygen supply to skeletal muscle. Static exercise like lifting heavy weights increases also the diastolic BP due to higher total peripheral resistance.

1.3.1.4. Reflexes and Hormonal Regulation

Baroreceptors in the carotid sinus and aortic arch detect BP changes and relay signals to the medulla oblongata, which modulates HR via vagal efferents, while chemoreceptors in the carotid and aortic bodies adjust responses to blood oxygen levels. Additionally, the Renin-Angiotensin-Aldosterone System (RAAS), initiated by renal blood flow changes at juxtaglomerular cells, regulates BP and volume (12). Vasopressin, released from the posterior pituitary in response to extracellular fluid hypertonicity, controls water retention to maintain osmolarity and blood volume homeostasis (13).

1.3.1.5. Adaptation to Exercise

Regular dynamic exercise lowers resting BP through vascular remodelling and increased capillary density, aiding in long-term CV-health (14). Maximal oxygen uptake (VO_2max) serves as a key indicator of CV-efficiency, with oxygen extraction rates at rest almost tripling under extreme physical exertion. Cardiac output can rise four- to fivefold in non-athletes, elite athletes achieve even higher cardiac output levels due to higher SV with slightly reduced peak heart rate (HR_{max}) (15). Exercise tolerance is influenced by factors such as adequate ventricular filling, oxygen extraction efficiency and thermal regulation. In athletes, the heart adapts with increased diastolic volume and SV (eccentric hypertrophy), allowing a higher cardiac output during intense exercise. The greater the muscle mass used at the same time during training, the more likely a systemic BP-lowering effect can be expected. Regular exercise gives the body time to adapt, in short-term increasing dilatation of arteries, on the long-term angiogenesis and blood vessel remodelling with increasing luminal diameters. The endothelium acts as a major organ, it interacts with nearly all bodily systems, influencing neurological, renal, cardiac, and immune health, and plays a key role in children's growth and immunity. Microcirculation in capillaries is influenced by endothelial function, regulating processes such as passage, cellular adhesion, and angiogenesis, mediated by factors like vascular endothelial growth factor (VEGF) and angiopoietin. Arterial and venous compliance, essential for regulating blood flow, is affected by the Bayliss effect - a response where blood vessels adjust to pressure changes within certain limits (brain: 50–120 mmHg; kidney: 60–180 mmHg) (16). At BP beyond these pressures, they act passively which predestines for CV-disease.

1.3.2. Respiratory system

During ventilation the respiratory system ensures that oxygen reaches our cells and carbon dioxide is expelled. Gas exchange, regulating blood pH, vocalisation, olfaction and protection against pathogens are some key features. The Euler-Liljestrand mechanism is a unique response of the lungs, resulting in adjusted blood flow to different regions of the lung based on oxygen availability, enhancing gas exchange efficiency. The body adjusts breathing rate and depth to momentary needs, vital capacity refers to the maximum amount of air a person can exhale after a maximum inhalation, an indicator of respiratory health. Total lung capacity is moderately to highly heritable, with larger lung volumes often correlating with a higher maximal oxygen uptake. Fat-free mass seems to be the dominant predictor of peak oxygen uptake (17). When exercise intensity surpasses the anaerobic threshold, lactate levels rise, and pH decreases. This results in oxygen deficit and metabolic acidosis, leading to increased respiration and heart rate, indicators of progressive fatigue. Performance diagnostics typically distinguish between thresholds coupled to blood-lactate levels during exercise (18). The aerobic threshold occurs around lactate levels of 2 mmol/l, where lactate clearance equals production. The anaerobic threshold, also called lactate turn point, occurs at lactate levels of 4 mmol/l, but can vary slightly. In between the aerobic-anaerobic transition (lactate levels 2 to 4 mmol/l) takes place. Once the performance parameter has been determined for the given threshold values, measures can be used for further training planning (zone classification, zone 1-5). For example, basic endurance training in zone 2 happens between aerobic threshold and anaerobic threshold (19). In untrained individuals, lactate concentration can reach 10 mmol/l, while in trained individuals, it can exceed 20 mmol/l. Lactate breakdown primarily occurs in the liver, skeletal muscles, and heart, where lactate is converted to pyruvate and then used for adenosine triphosphate (ATP) production, gluconeogenesis or glycogen replenishment. Training enhances lactate tolerance and degradation rate, aiding in muscle recovery and supercompensation.

1.3.3. Mitochondria

Mitochondria can occupy a significant proportion of muscle volume - about 2-10% depending on the fibre type (20). This high mitochondrial density supports the energy

needs of active muscle tissues by maximizing ATP production capacity. They play a crucial role in muscle function, energy production, and athletic performance. In trained athletes, the number and volume of mitochondria in muscle cells can increase, enhancing the cells' ability to sustain prolonged, high-intensity exercise. At low to moderate exercise intensities, mitochondrial ATP production can efficiently meet energy demands. However, during high-intensity or sprint activities, ATP demand can surge up to 100 times the resting level, surpassing the mitochondria's maximum ATP production rate by about 2-3 times (21). At these levels, energy must also be generated through anaerobic pathways, leading to lactate build-up and muscle acidosis. High energy demand also accelerates the generation of reactive oxygen species due to the intense electron transport chain activity (22). This requires robust mitochondrial antioxidant systems to protect cells from oxidative damage. Nevertheless, PA compared to sedentary behaviour (SB), remains an important foundation for healthy aging and mitochondrial biogenesis (23).

1.3.4. Metabolism & Energy expenditure

Metabolism is essential to support all cellular functions for growth, movement and reproduction. The balance of energy intake and expenditure is crucial for maintaining body weight. It is influenced by a combination of metabolic rate, energy storage, and physical activity. Biochemistry gives a coherent explanation how carbohydrate, protein and lipid metabolism is realized on cellular basis. These processes are induced or slowed down by hormonal signals, a complex interplay between insulin and glucagon, incretins glucagon-like peptide 1 and gastric inhibitory polypeptide (GLP-1, GIP), cortisol, thyroid hormones and many more. The glycogen storage located in liver cells is guaranteeing a balanced blood glucose homeostasis. Cholesterol and lipid balance is enabled by lipoproteins, HDL responsible for reverse cholesterol transport, while LDL carries cholesterol to adrenal gland, gonads, muscle and adipose tissue for receptor-mediated endocytosis. On its way it can get oxidized inside the intimal wall inducing atherosclerosis, intensified by lifestyle risk factors (24). The symptom complex of visceral fat accumulation, hypertension, insulin resistance and systemic inflammation is summarized as metabolic syndrome, which is not only affecting grown-ups, but gradually becoming apparent in childhood as well, but with minor discrepancies for a clear definition (25).

Appetite and satiety are under hypothalamic control. Neuropeptide Y/agouti-related peptide (NPY/AgRP) neurons stimulate appetite, while proopiomelanocortin/cocaine- and amphetamine-regulated transcript (POMC/CART) neurons restrain it (3). Ghrelin stimulates hunger, while leptin and insulin curb it. Chronic over-nutrition may lead to leptin resistance. Energy expenditure during digestion and nutrient absorption varies by macronutrient type described by specific dynamic action. A positive energy balance leads to storage of energy in adipose tissue. For fat reduction a caloric deficit of approximately 7000 kcal per kilogram body fat loss is required. Brown adipose tissue plays part in thermoregulation and is activated by cold exposure (26). This leads to amplified energy expenditure by burning lipids to generate heat, contributing to a net-negative energy balance for weight loss, and could have future therapeutic potential (27). Brown fat activity is inversely related to BMI and age. Historically often seen as passive storage, adipose tissue has many physiological functions in regulating metabolism, food intake, body temperature as well as providing cushioning as protection from injury. Adipose tissue dysfunction can lead to the excessive deposition of lipids in other organs like liver and muscle, which contributes to insulin resistance and metabolic disease (28).

1.3.5. Energy compensation

There is increasing evidence that a long-term raise of PA does not directly lead to an increase in total energy expenditure, because the body has subtle ways to decrease other physiological processes in response to high energy expenditure, this proposed concept is called energy compensation (29). Basal energy expenditure could be throttled down nearly by a third due to shortage of metabolizable energy sources. Cyclins, cyclin-dependent kinases as well as transcription factors finely adjust the intracellular signal transduction, consequently influencing cellular processes and epigenetic adaptation (30). Cellular nutrient sensors such as mechanistic Target of Rapamycin (mTOR) complexes 1 and 2 determine whether the cell grows, divides, or conserves energy (31). This challenges explanations by simple math and complicates basic thermodynamics, because adaptable biological systems have subtle ways to counteract introduced stressors. An interpersonal variability of energy compensation could help us understand, why some people tend to have less problems maintaining a healthy body weight than others. Further contributing

factors to body weight stability are light PA and SB throughout the day, as well as unique periodization of meal intake and behavioural responses to fasting periods (32).

There are two conclusional models trying to explain how obesity manifests (33). The energy balance model posits that weight gain occurs when energy intake (calories consumed) exceeds energy expenditure (calories burned). This model emphasizes that total caloric balance is what drives changes in body weight. Calories have equal potential in contributing to weight gain, for weight management a caloric reduction by reducing food intake or increase PA is recommended. The carbohydrate-insulin model (CIM) suggests that obesity is driven primarily by the hormonal effects of high carbohydrate intake, particularly refined carbohydrates and sugars. Foods with high glycaemic index increase insulin secretion, which promotes fat storage and reduces the body's ability to burn fat for energy. High insulin levels cause an anti-lipolytic effect and create a metabolic environment where the body prioritizes storing calories as fat, rather than using them for energy (34). This can lead to increased hunger and decreased energy expenditure, predestine for weight gain. With the CIM, the best way to lose weight is keeping insulin levels down and by that, promoting fat burning and preventing increase in body fat.

A combined approach leads to understanding that overshoot energy expenditure and increased amount of food with high glycaemic index, like high-carbohydrate diets and large amounts of simple sugars, lead to growth of adipose tissue and thereby weight gain with all associated consequences. When analysing body weight changes via simple scales, the factor of body composition should always be considered, encouraging reduction of fat mass, while maintaining or increasing muscle mass.

1.3.6. Nutrition

Nutrition is a key component for counteracting the pandemic of childhood obesity. Primary school children are in phases of major growth and development, and they are also establishing their eating habits. Teaching the importance of a balanced diet and understanding basic food components is essential during these formative years. A balanced diet should include a proper mix of macronutrients:

- 55-60% from complex carbohydrates high in fibre (whole grains, fruits, vegetables)

- 25-30% from healthy unsaturated fats, rich in omega-3 and omega-6 fatty acids, sourced from nuts, seeds, fatty fish and olive oil.
- 10-15% from proteins, which are vital for cellular structure, enzyme production, hormone synthesis and tissue growth and repair.

Preferred carbohydrates should have low glycaemic index, leading to smaller blood glucose spikes, therefor less glycaemic variability and glycation, as well as lower insulin secretion. In addition to macronutrients, specific micronutrients are critical for children's health. Vitamin D supports bone health, calcium absorption and immune function (35). Vitamin C serves as an antioxidant and aids immune function and tissue repair. B vitamins are necessary for energy production, red blood cell formation and neurological function. Essential minerals like calcium, iron, magnesium, and zinc contribute to overall health and development. Adequate water intake should be encouraged, while sugary beverages and fruit juices should be limited. The Mediterranean diet emphasizes fruits, vegetables, whole grains, lean proteins, healthy fats and is both scientifically supported and sustainable, offering a model of nutrition that benefits health and supports environmental sustainability (36,37). The diet goes along with a favourable body composition in children during early development (38). Promoting food biodiversity and sustainable agricultural practices is beneficial for both health and the environment. Emphasizing plant-based foods, reducing food waste, and choosing locally sourced, seasonal foods can help build a sustainable food system, supporting planetary health alongside children's nutrition.

1.3.7. Effects of exercise on the musculoskeletal system

Skeletal muscle is composed of three main different muscle fibre types, depending on the myosin heavy chain (MyHC), slow-oxidative MyHC type I, fast oxidative-glycolytic MyHC type IIA and fast-glycolytic MyHC type IIX (20). Different exercise types have different impact on muscle tissue. Slow oxidative muscle fibres are associated with endurance and respond optimally to long zone 2 training. With resistance training, to maximize hypertrophy, 12 to 20 sets per week should be sufficient (39). When optimizing active learning during school, aspects of sports physiology must be considered to optimally benefit children's health. Throughout childhood, muscle mass grows steadily, under

combined influence of PA, nutrition and hormones. Muscle mass then remains the biggest contributing factor influencing energy metabolism throughout life.

Bones in children adapt and remodel in response to the mechanical loads they experience, biomechanical stressors promote healthy bone growth and density. PA like running and jumping exert forces on the bones, resulting in strengthening and trabecular remodelling. Caution for overloading and the higher vulnerability of unfused epiphyseal plates must be considered to avoid injury. Through endochondral ossification bones grow in length at the epiphyseal plates, primary cartilage models are gradually replaced by bone, height increase and overall skeletal growth increases. By perichondral ossification larger diameters and thickness are established. The period of highest growth rate is known as peak height velocity. For girls, this maximum growth spurt typically occurs around age 11, with an increase of 7 cm per year, while for boys, it generally occurs around age 12, with growth rates reaching 8 cm per year (40). The difference in final height mainly occurs due to longer duration of prepubertal growth of boys (41). Peak bone mass (PBM) is the maximum bone density and strength a person achieves, typically around late adolescence to early adulthood. The higher the PBM achieved, the better the protection against osteoporosis and fractures in later life. Around 30% of PBM can be addressed to environmental and behavioural factors (42). Daily school PA in children and adolescents is associated with beneficial gains in bone traits and lower relative fracture risk (43).

1.4. Pathophysiology of health risk and association of obesity

There are several identified risk factors associated with CV and metabolic disease in elementary school children, some of them are more obvious than others. Figure 3 gives an overview of important influential aspects to the pathogenesis, as well as with obesity correlating health risks. When considering addressing these issues as a health care profession, a focus should be set on providing understandable information and applicable steps toward better health, adjusted to age and individual background.

High-risk conditions demand for intensified measures and more continuous medical support, e.g. homozygous familiar hypercholesterinaemia, Type 1 and Type 2 diabetes, secondary causes of hypertension, genetic syndromes, renal diseases or children with

Kawasaki disease. In such cases, a risk stratification and assessment of risk factors must not be missed, providing valuable information for treatment goals and therapy.

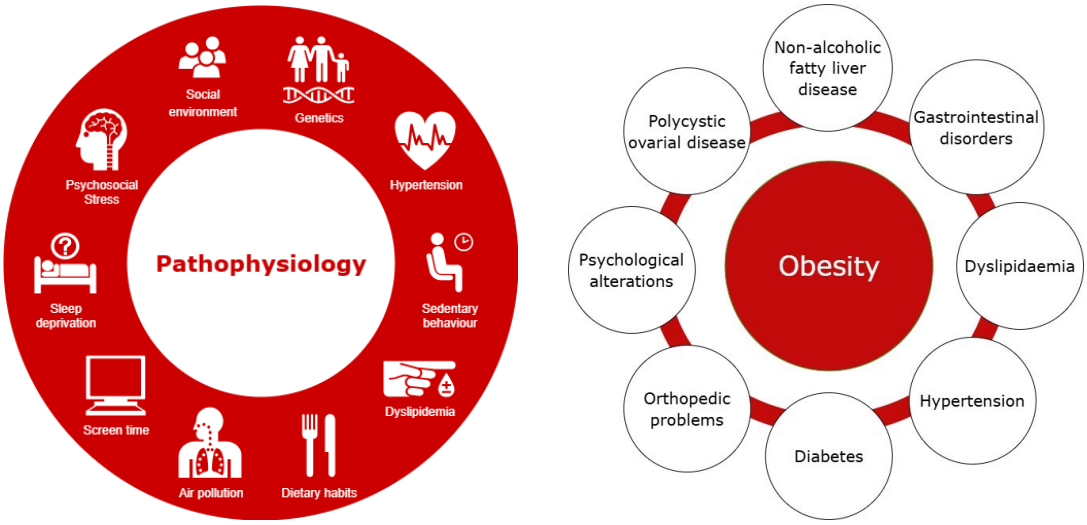


Figure 3 - Pathophysiology of health risk and associations of obesity

1.4.1. Genetics - Familial Predisposition

Children with congenital heart disease are particularly affected by overweight (44). Common congenital heart anomalies are ventricular septal defect, atrial septal defect, persistent arterial duct Botalli, bicuspid aortic valve and aortic stenosis. Hypertrophic cardiomyopathy is caused by alterations in sarcomeric proteins, leading to symmetric hypertrophy of the left ventricle, with septal hypertrophy being the most prominent feature. This can obstruct blood flow and impair cardiac function making it a leading cause of sudden cardiac death in athletes, often without prior symptoms presented. Dilated cardiomyopathy results in dilatation and impaired contraction of one or both ventricles, most commonly the left ventricle. It is often triggered or exacerbated by an episode of myocarditis, symptoms include heart failure, arrhythmias up to sudden cardiac death (45).

With a history of CV disease in families there is a combined influence of genetic, biological, behavioural, and environmental factors to consider. When there are signs that a genetic predisposition given, for example relatively young members before the age of 55 years affected by CV disease, all close family members should be addressed for potential CV risk factors.

In metabolic illnesses, twin studies estimate a 70% genetic predisposition to obesity, influenced by daily energy metabolism (46). For type 2 diabetes mellitus, monozygotic

twins have a concordance rate above 50% - a much higher genetic predisposition than in type 1 diabetes. There are also several affected gene-types of maturity-onset diabetes of the young (MODY). These diabetic diseases result in accelerated atherosclerosis, an early screening for clinical CV disease is recommended. Lipid disorders like familial hypercholesterolemia can cause xanthelasma, early coronary artery disease, and transient ischemic attacks. Heterozygous familial hypercholesterolemia occurs in approximately 1 per 300 children (47). Certain genetic traits can be protective against CV disease, for instance genetic variations linked to lower cholesterol levels, resulting in increased life expectancy.

1.4.2. Hypertension

Elevated BP during childhood is a predictor of increased risk for developing hypertension in adulthood. In 2015 the prevalence of hypertension among 6-year-olds was 4.32%, notably higher in overweight and obese children (4). From 2000 to 2015 there was a significant upward trend with a relative increase around 76% in hypertension prevalence. This rise is partially attributable to increasing rates of childhood obesity, with BMI remaining the strongest modifiable risk factor for hypertension in children.

BP in children above the 90^{th} percentile or >120/80mmHg is classified as elevated BP. To identify manifested hypertension at least three individual, valid measurements, above the 95^{th} percentile of the age norm, are required. Secondary hypertension in children may arise in multiple scenarios, including CV, renal, endocrine causes, for example aortic coarctation, glomerulonephritis, renal artery stenosis, pheochromocytoma, Cushing's syndrome and others.

Prolonged hypertension results in damage of various tissues leading to hypertensive and ischemic heart diseases, arrhythmias, aortic and mitral valve diseases including stenosis or insufficiency and accelerated calcific degeneration, chronic kidney injury, progression to heart failure, aortic dissection and aneurysm formation. Therapeutic strategies include causal treatment as well as lifestyle modifications, such as weight normalization, dietary changes, relaxation techniques and regular dynamic endurance training.

A meta-analysis of 270 randomized controlled trials demonstrated that various exercise modalities significantly reduce resting BP, with isometric exercise being the most effective,

with a sysBP reduction of 8.24mmHg (48). These findings highlight the importance of incorporating isometric and combined training, as well as aerobic exercises to encounter the current development. Reducing childhood hypertension as a preventive measure has high potential and is critical to mitigating long-term CV complications later in life.

1.4.3. Sedentary behaviour

Physical inactivity is a leading modifiable risk factor for CV disease and all-cause mortality (49). Energy expenditure of waking behaviour below 1.5 metabolic equivalents (MET=1kcal/kg/hour) classifies as SB, while PI refers to insufficient moderate to vigorous activity. SB and PI are both linked to mitochondrial dysfunction and subsequent DNA damage (50). Extended sedentary time correlates with an increase in larger VLDL particles, higher systolic blood pressure and obesity. Breaking up long periods of sitting can mitigate some negative effects on CV health, regardless of adiposity.

According to the COSI study, children's PA habits vary significantly (2). About half of children use active transportation (e.g. walking or cycling) to and from school, with variations between countries (18%–94%). A majority plays outdoors for at least an hour daily (62%–98%), but just a smaller percentage engages in organized sports for at least two hours per week (10% to 75%). A study, published in 2022, gathered accelerometer data of Norwegian children, showing that the introduction of smartphones, tablets and ubiquitous internet access increased sedentary time around 20-30 min per day (51). A similar development can be assumed in Austria, negatively affecting children's health. The interdisciplinary guideline on the prevention and treatment of obesity encourages simple measures to reduce PI, such as reducing media consumption, contributing significantly to weight loss and shown to be more effective on long term to sustain weight loss (52). A goal of 12,000 steps per day is recommended, with a total of 90 minutes or more of moderate to vigorous PA per day for children, even exceeding the WHO guidelines (53).

1.4.4. Dyslipidemia

The growing prevalence of childhood obesity has increased the number of children with dyslipidaemia. Elevated LDL cholesterol and lipoprotein(a) levels contribute to the formation of fatty streaks and inflammatory responses, accelerating the process of arteriosclerosis. The PDAY study demonstrated that already in adolescents an increase in

non-HDL cholesterol was corresponding with a measurable rise in both the extent and severity of atherosclerosis (54). In the "Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents" Table 9-3 gives a comprehensive overview about causes of secondary dyslipidaemia(55). Identifying and controlling dyslipidaemia during youth benefits long-term CV health. Simple reliance on family history of premature CV disease for identifying children with dyslipidaemia has shown to be insufficient, as it misses up to two thirds of cases. When it comes to managing dyslipidaemia by adjusting nutrition, the CV health integrated lifestyle diet 1 (CHILD-1) focuses on a low-fat, low-saturated-fat, and low-cholesterol dietary pattern. If not yet successful, a further step with CHILD-2 diet emphasizes caloric reduction, increased PA, and behavioural interventions including family support. Engaging with a registered dietitian can effectively help with dietary changes in family settings. If the intensive management still has not led to successful risk mediation, in a fifth step, drug therapy should be considered. Treatments such as statins and proprotein convertase subtilisin/kexin type 9 (PCSK9) inhibitors are applicable for reducing LDL cholesterol levels, mitigating early atherosclerotic processes.

1.4.5. Obesity

The likelihood of becoming obese is often already determined in early childhood, as BMI tends to proceed into adolescence and adulthood. Overweight in childhood is not simply defined by BMI, but by age-specific percentiles. Overweight is reached at the 90^{th} percentile, obesity is classified at the 95^{th} percentile or 97^{th} percentile, depending on the regionally preferred definition. The increased body weight may also be a symptom of a pre-existing eating disorder, for example binge-eating disorder (56). Obesity is intertwined with significant reduction in life expectancy and overall mortality (57). Elevated risk is due to hypertension, type 2 diabetes, stroke, as well as certain cancers such as oesophageal adenocarcinoma, post-menopausal breast cancer and colorectal cancer (58,59). Increased perivascular adipose tissue leads to adipokine dysregulation, excess fat-deposits cause elevated transaminases, abnormal LDL- and HDL-levels, increased basal inflammation as well as structural overload and early arthrosis (60). Around half of the affected children show negative consequences for liver health, with metabolic dysfunction leading to steatotic liver disease, making them vulnerable for liver diseases in adolescence and

adulthood (61). Prevention is the key to positively influence children's obesity rates, this can include extended periods of breastfeeding, early monitoring of anthropometric percentiles, reduction of nutritional sugar intake and limiting fruit juice consumption (62). To address transgenerational obesity, family-based programs that focus on parental involvement, structured exercise training, and reducing SB are essential for promoting long-term healthy habits in children. Continuous glucose monitoring could provide remedy for obese children by identifying glycaemic dysregulation, learning to reduce blood sugar spikes and avoid further increase in adipose tissue (63). Failure to implement effective preventive measures at an early stage leads not just to increased individual suffering, but also enormous economic consequences at a later stage, in form of initially avoidable disability or increased medical spending, for example due to post-operative complications or expensive medication, including GLP-1 agonists. Nevertheless, GLP-1 agonists, which may soon be available in oral form, can lead to significant weight loss, for cases where otherwise no sufficient improvement through lifestyle intervention could be achieved (64). Many effective and long-term solutions will be required for the high-priority goal to reduce future rates of cardiovascular-kidney-metabolic syndrome, an expanded concept proposed by the American Heart Association in 2023 (65).

1.4.6. Dietary habits

Primary school children are often confronted with energy-dense, nutrient poor foods, especially sugar-sweetened beverages leading to spikes in blood glucose levels, resulting in weight gain. Along come changes in family life, dictated by current times, causing irregular family meals and meal timing, leading to more solitary eating or eating on the go, with disengagement from meals. COSI reported that despite 80% having a regular breakfast, one-third of Austrians primary schools lacked access to fresh fruit (2). Only 25% of children consumed vegetables daily, around 45% of children consumed fruit daily. A quarter of children reported frequent consumption of sweet snacks, compared to 14% for savoury snacks. Contribute substantially to non-alcoholic fatty liver disease, current guidelines for obesity prevention highly recommend limiting unhealthy snacks and sugary soft drinks (52). For children a simple traffic light system such as NurtiScore may help with these choices, marking products green that can be consumed in abundance. Red foods are

energy-dense (or provide few nutrients in relation to their energy content) due to a high fat content or simple carbohydrates. At home they will need support adjusting healthy eating habits with the entire family, seizing opportunities to eat beneficial meals together. During time at school, local school food service policies are one promising way to increase fruit and vegetable consumption (66). Great initiatives such as nutritional recommendations from "Richtig Essen von Anfang an!" by the Austrian Agency for Health and Food Safety GmbH and the Federal Ministry of Health need to reach families so that through acquired knowledge health-promoting behaviours can be established. Children are also a vulnerable target for marketing of unhealthy food options, often confronted online via smartphones. Platforms like YouTube, Instagram and other social media have direct access to children's attention without an easily accessible actuator. A study from 2023 conducted by the Medical University of Vienna, Center for Public Health, showed that a large proportion of the advertising shown is classified as not permitted for advertising to children (67). Legal action should be considered where weaknesses in current regulations are being exploited.

1.4.7. Screen time

Screen time among primary school children increased significantly due to the coronavirus pandemic, even before COSI study reported only around 60% of children had a daily screen time less than 2 hours (2). Common recommendations for 6 to 9-year-olds are a maximum of 30–45 minutes of free screen time per day, with suggested use of parental controls. With 9 to 12-year-olds duration increases to a maximum of 45–60 minutes per day. A weekly time allowance can help to make usage more flexible. Notably boys are more prone to increased screen time than girls. 40% of children have screen time above 2 hours a day, beyond doubt when adding up TV-watching and electronic device usage, intensified during weekends. This is worrying insofar as there is increasing evidence of harmful dose-effect relationship of technology usage for mental health in adolescents (68), it could be that younger children are be even more vulnerable. For young children 3 to 6 years daily screen time was associated with slightly higher non-HDL cholesterol (69). Limiting screen time for example banning TVs from bedrooms and charging smartphones outside the bedroom can not only reduce sedentary time and increase sleep duration but also lower the risk for

myopia (70). Clear rules as well as media usage agreements aid in sustaining screen time inside healthy boundaries. Non-media leisure activities such as sports or creative hobbies as well as outdoor activities with friends may help reducing dependence on screens.

1.4.8. Second-hand smoke exposure - Air pollution

In 2011 Lancet published that 40% of children worldwide were exposed to second-hand smoke (SHS), mainly one of their close relatives smoking at home (71). Children experiencing SHS exposure show an increase in asthma prevalence and exacerbations due to attenuated endothelial function. SHS affects the respiratory system and may intensify lower respiratory infections, including symptoms of breathlessness and wheezing. Lower pulmonary function test results have been observed and the risk to be hospitalized with asthma exacerbation is nearly doubled (72). The disease burden of SHS is causing up to 6.6 million DALYs in children. In areas experiencing air pollution these negative health consequences may be intensified. There are signs that exposure to air pollutants in childhood, especially to fine particles (PM2.5) and nitrogen dioxide (NO_2) are associated with elevation of diastolic BP and negative neurodevelopmental outcomes (73,74).

To counteract the SHS and air pollution effects steps should be taken to provide a smoke-free environment at home and less air pollution in public. This includes anti-smoking advice in childhood and offering help to all family members to quit smoking. The WHO recently published their clinical treatment guideline with evidence-based recommendations for smoking-cessation, including the 5 A's (ask, advise, assess, assist, and arrange) (75). Protectives are other simple measures like more street trees, reducing prevalence of early childhood asthma (76). The shift from combustion engines to electric mobility and public transportation may also contribute positively, although emissions from tire wear and brake pads remain, more detailed results from future research must be waited for.

1.4.9. Social environment - Socioeconomic circumstances

Our social environment provides the framework in which self-efficacious acts can take place (77). Especially in childhood there is little choice but to live in the one we are born into, this includes provided economic and social resources and resulting increased or reduced stress level (78). Children lacking resources are in danger of being overwhelmed by immediate challenges, which makes them more vulnerable for adverse health

outcomes. Without support and stimulation, the risk for depression, anxiety and low self-esteem considerably increases. This can lead to negative self-perception and negative worldviews, promoting difficulty in building social skills, close human bonds or initiating health-protective behaviour. Some important risk factors are a low socio-economic status, mental disorders of mother or father, relationship pathology inside family or severe loss, like death of close family members. This may also have a large impact on children's school performance and further educational success, whether it be completing high school, learning an apprenticeship profession or successfully studying at university. Children from parents with low education have a three times higher risk of obesity at age eight, independent of household income (79). COSI reported that children of more educated parents more often engage in sports and dancing than children of less educated parents, although the probability that they walk or cycle to and from school is vice versa (2). In search for obesogenic environmental factors potential detrimental effects like underfunded school districts, unsafe neighbourhoods, close fast-food restaurants should not be overlooked (80). Environments positive impact includes access to green space and sports facilities, healthy fruit and vegetable markets. Other protective factors are a high socio-economic status, resource activation, above-average intelligence as well as a lasting good relationship with at least one primary caregiver, offering needed appreciation and endorsement throughout childhood.

1.4.10. Psychosocial Stress

Children with overweight regularly experience teasing by peers, friends, family members or even strangers, the stigma and judgment about their weight can have serious effects on their psychological health (81). Risk factors for obesity also include parental depression, parental anxiety or experiences of loss. There is a common misperception that blaming or shaming kids for their weight leads to a motivation for weight loss, instead it results in distress, issues with sleep and has negative effects on eating habits, which often makes things worse (82). The additional weight gain lowers their self-esteem and confidence, sometimes propagates behavioural problems like acting out or showing anger (83). There should be a focus on helping kids with obesity, often already confronted with difficulty in their social environments, making them feel valued and support their feeling of self-

efficacy. In an environment acknowledging the difficulty of weight loss and its maintenance, one that is promoting kindness and empathy toward people with overweight, where obese children are given a chance to learn and implement beneficial habits like good nutrition, regular physical exercise and longer sleep durations.

1.4.11. Sleep deprivation

Sleep being essential for maintaining homeostasis and adaptation, humans spend about a third of their lives asleep. During sleep children's growth hormone levels peak, allowing growth and regular physical development. A sufficient time of high-quality sleep plays major part in neurodevelopment and mental health resilience. Rapid-eye movement (REM) sleep supports adequate memory consolidation, with long-term potentiation strengthening synaptic connections, especially emotional memories, and long-term depression weakening less important ones (84). Sleep also regulates insulin sensitivity, BP and promotes HR variability, as part of a healthy parasympathetic nervous system function (85). Non-REM sleep is lowering cortisol and adrenocorticotropic hormone (ACTH), helping to reduce stress and inflammation, making children less susceptible to infections (86,87). Poor sleep increases risk for obesity, making children susceptible for unhealthy dietary patterns (88). With higher prevalence of obesity hypertension and obstructive sleep apnoea rates increase, accompanied with further negative impact on sleep pattern and overall CV risk.

Children's needed sleep duration varies by age. At six years old, children generally require about 10 to 12 hours of sleep per night, while at 12 years old they need around 8-10.5 hours. Sleep pressure is created during the day by accumulation of adenosine, until sleep is unavoidable. Orexin, released by the lateral hypothalamus, promotes wakefulness. Caffeine can temporarily block adenosine receptors, creating awake feeling. Although the COSI report suggest that 80% of European children sleep at least 9 hours per night (dropping to less than half when threshold was set to 10 hours), data was provided by questionnaire filled in by parents (2). There is still need for randomized controlled trials and intervention studies providing reliable data of objectively measured sleep to examine changes in different outcome measures.

1.5. Health Promoting Schools

The potential of early health improvement in childhood was recognized many years ago. A synthesis report by the Health Evidence Network published in 2006 highlighted that a holistic, multifactorial approach including students, staff and parents was generally more effective (89). Promotion of mental health, preventing violence and adjusting school environment to develop personal health skills were most promising.

Figure 4 - Health promoting schools – School environment in Austria (Graz)

Figure 4 emphasizes that encouraging health advancement should include a wide variety of sub-areas, each of which has an impact on children's health. Active learning and maintaining connection to nature makes it fun and can help realizing future visions for generations to come. In 2014 a review of health promoting schools by the WHO showed that a setting approach had positive results for some of these aspects, such as fruit and vegetable consumption, tobacco use, PA and bullying, but with generally small effects (90). Based on the School Buffet Guideline from 2011, a new School Buffet Guideline was published in 2024, by the Federal Ministry of Social Affairs and Health under Federal Minister Rauch (91). These provide a well-thought-out basis for the range of food and beverages on offer and the contents of vending machines. The aim was to promote healthy snacks, water as ideal thirst quencher and, for example, limiting the packaging size of sweets to a maximum of 30 g. Nevertheless, there is still room for improvement, to reduce or completely ban the sale of sweetened beverages. A major challenge that remains is adapting whole school environments combined with the behaviour of entire families, implementing health-promoting changes to the widest possible range of influencing factors.

1.6. Aims and objectives

Targeting physical education lessons for better health-related physical fitness outcomes a meta-analysis of 2020 reported mild reduction in BMI, waist circumference, body fat, and increases in lean body mass, cardiorespiratory fitness and muscle strength (92). Guidelines for cardiovascular health and risk reduction in children and adolescents from 2011 suggest an increase in moderate-to-vigorous PA to lower BP, improve fitness and beneficially influence BMI and cholesterol levels (55). There a promotion of PA is recommended, with isometric exercises being most effective for BP, especially if combined with aerobic and dynamic resistance training.

The potential of reaching all children of society, regardless of their socioeconomic background, social environment or health behaviour inside families was a key driver for initiating the "Happy Children" project, aimed to positively influence current worrying developments at an early stage. To measure and objectify aspects of health using decisive parameters, this thesis selected systolic BP and endurance performance in the form of running, and their changes throughout the study as indicators of CV health. The non-invasive and easily measurable parameters BMI and WHtR were selected as indicators of metabolic health, with some associated limitations, but to maintain high ethical standards

1.7. Hypothesis

The existing curriculum in elementary school was adapted to positively influence the health of the participating children. Regardless of existing regular physical education classes, 45 minutes of physical activity in form of active learning during theory lessons were incorporated on a daily basis. To evaluate our approach the following null hypotheses and alternative hypotheses were proposed:

Null hypotheses:

▪ H0:[1] There are no differences in the change of cardiovascular health and physical fitness depending on the exercise intervention in students at the intervention schools in comparison baseline to follow-up.

Differences in terms of

- Systolic Blood Pressure (sysBP)
- Endurance - Andersen Running Test (VO_{2max})

from baseline to follow-up between children in the intervention school compared to the control school.

▪ H0:[2] There are no differences in the change of metabolic health depending on the exercise intervention in students at the intervention schools in comparison baseline to follow-up.

Differences in terms of

- Body-mass-index (BMI)
- Waist-to-height ratio (WHtR)

from baseline to follow-up between children in the intervention school compared to the control school.

Alternative hypotheses:

▪ H1:[1] There are differences in the change cardiovascular health and physical fitness depending on the exercise intervention in students at the intervention schools in comparison baseline to follow-up.

Differences in terms of

- Systolic Blood Pressure (sysBP)
- Endurance - Andersen Running Test (VO_{2max})

▪ H1:[2] There are differences in the change of metabolic health depending on the exercise intervention in students at the intervention schools in comparison baseline to follow-up.

Differences in terms of

- Body-mass-index (BMI)
- Waist-to-height ratio (WHtR)

from baseline to follow-up between children in the intervention school compared to the control school.

2. Material and Methods

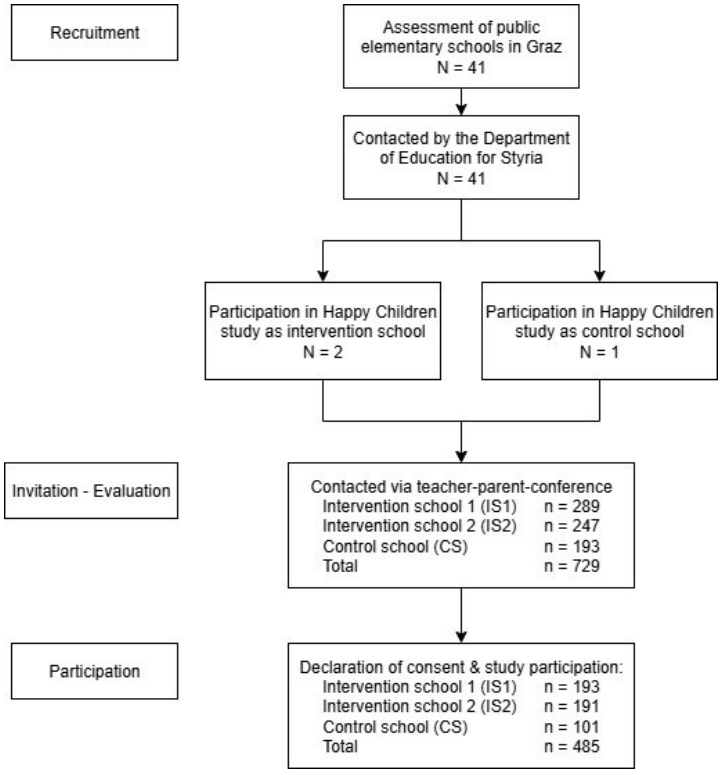
2.1. Design

The study was part of the project "Optimizing cardiometabolic Health, Cognition and Academic Performance with Happy Children (HAPHC) using school-based physical activity" in Austrian primary schools in Graz (93). It was initiated by the Division of Physiology & Pathophysiology - Otto Loewi Research Center for Vascular Biology, Immunology and Inflammation, Medical University of Graz, in cooperation with the Department of Education for Styria. The three-year non-randomized controlled intervention study involved two intervention schools and one control school, starting in September 2021 until the end of June in 2023. Registration was performed at ClinicalTrials.gov (NCT04956003). Audit was carried out by Research Ethics Committee of the Medical University of Graz (33-488 ex 20/21).

2.2. Selection process

Integrating new teaching methods and structural adaptation of lessons demand a high degree of willingness to change and motivation from participating schools and teaching staff, which is why the voluntary participation in the study was explicitly emphasized.

An invitation to participate in this project was sent out by Board directorate of Education for Styria in February 2021. In response to this letter, two schools out of 41 - differing in terms of catchment area - applied to participate (Figure 5). As a control school, a school that matched one of the two intervention schools in terms of catchment area was contacted and willing to join. It should be noted that the two intervention schools differed largely in terms of socio-economic status. Intervention school 1 (IS1) is in a more affluent district, the other two schools, intervention school 2 (IS2) and control school (CS) are more similar in terms of socioeconomic and migrant-proportion background.



IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; N = number of schools; n = number of participants

Figure 5 - Recruitment and study participation

2.3. Criteria

2.3.1. Inclusion criteria

All primary school children between 6 and 11-years of age.

2.3.2. Exclusion criteria – none

2.3.3. Randomisation – none

2.4. Trial procedure

The intervention schools, two urban primary schools from divergent catchment areas, were instructed in performing a daily 45 minute-unit of moderate to intensive physical activity as an integral part of learning. The control school proceeded unchanged from usual teaching style. After providing parental information and attaining declaration of consent for the planned physiological examinations and tests, in all three schools the same tests and examinations were carried out, at the beginning of the study in 2021, as well as at the end of every school term. This resulted in the measurement times for baseline measurements (BM) in October 2021, First Follow-up (FU1) in June 2022, Second Follow-up (FU2) in June 2023.

2.5. Intervention

The regular curriculum with existing sports lessons was adapted with additional 45-minute learning in motion during theoretical lessons to avoid long periods of sitting as well as to restore children's attention span. Prior to the start of the intervention teachers were coached by PPH Graz (Private Pädagogische Hochschule Augustinum) for new forms of teaching targeting the daily increased physical activity goals. A blueprint for realizable and feasible learning in motion units was provided by teachers from Norway, already participating in the HOPP project. The joy in partaking these exercises led to pupils actively demanding intervention from the teachers. The regimen was monitored and documented on a weekly basis by the lecturers.

Active learning in motion was adapted to lessons and educational content. This led to simple exercises such as running around, jumping jacks, jumping in the air, galloping, or hopping on one leg. Squats and jumping on both legs promoted leg strength and endurance. Coordination and balance exercises, such as movement ABC or the hacky sack (footbag) improve body control and motor skills. Playful activities such as whole-body Ching-Chang-Chong or exercises with a gym ball ensured fun during everyday learning.

Commands in a first foreign language (English) were creatively incorporated, such as "jump," "turn," or "freeze", linking language learning with action. In the run-up to Christmas a movement Advent calendar ensured everyday surprise.

2.6. Collected data

2.6.1. Assessment of blood pressure

Systolic and diastolic blood pressure was measured with an Omron blood pressure monitor (Omron M400 Intelli IT, Omron CS2 small cuff) with accuracy of ±3 mmHg, a device with a test seal from the German High-Pressure Society for use on children. For children with an upper arm circumference >24 cm an adult cuff was used. Goal was to attain three representative blood pressure measurements. This could only be achieved with correct BP measurement practices in adherence to the "Guideline for Screening and Management of High Blood Pressure in Children and Adolescents", Table 7 by the American Academy of Pediatrics (94):

- The correct cuff size needs to be selected - the width at least 40% of the upper arm circumference - otherwise incorrectly high values can occur. If the cuff width is greater than ¾ of the upper arm length, smaller values are presented.
- The child should be seated in a quiet room for 3–5 min before measurement, with the back supported and feet uncrossed on the floor.
- BP should be measured in the right arm. The arm should be at heart level, 90° supported, and uncovered above the cuff. The patient and observer should not speak while the measurement is being taken.
- The correct cuff size should be used. The bladder length should be 80%–100% of the circumference of the arm, and the width should be at least 40%.
- The cuff should be inflated to 20–30 mmHg above the point at which the radial pulse disappears. Overinflation should be avoided, deflation at a rate of 2–3 mmHg per second. The first (phase I Korotkoff) and last (phase V Korotkoff) audible sounds should be taken as SBP and DBP, read to the nearest 2 mmHg.

For all children the measurement protocol included the 5 min seated resting period followed by three measurements with a 2 min interval in between. Multiple measurements over time were performed in the years of follow up at the end of each school year.

2.6.2. Assessment of body-mass-index

For body mass index, weight in kilograms and height in meters were measured during the first school hours. The measurements were performed in standardized manner, for correct height child standing upright, barefoot or with thin socks with their back against the flat wall and then measured at right angle. To determine body weight children got weighed in light clothing.

2.6.3. Assessment of waist-to-height ratio

For waist-to-height ratio (WHtR), correct waist circumferences in centimetres were needed, height in centimetres from BMI measurements were used. The waist circumference is measured while standing upright, halfway between the lower rib cage and the upper edge of the iliac crest, ideally after normal exhaling without sucking in your stomach. The tape measure should be horizontal, tight but not cutting into the skin.

2.6.4.Assessment of endurance – Andersen running test

The Andersen running test was used to determine endurance and aerobic fitness. This shuttle run test is a practical, cost-effective and reliable method to estimate maximal oxygen uptake (VO2max) in children and adolescents. The test lasts 10 minutes and involves running a 20-meter distance as many times as possible. Music is used to set the pace, with 15 seconds of running followed by 15 seconds of rest until the 10 minutes are up. In the sports hall, the 20-meter track was marked with parallel lines, and each child was assigned to a staff member who recorded the number of laps run and determined the total distance. The group size was 5-8 children per round, which encouraged motivation among the children while remaining small enough to avoid collisions or obstructions.

2.7. Statistical methods

All statistical analyses were performed using the SPSS statistical software, version 29.0 (IBM Corp., Armonk, NY, USA). Prior to analysis all raw data were checked for potential outliers and cleaned of erroneous data, for example data transmission errors during digitization. Descriptive statistics and comparison of baseline data to evaluate pre-existing differences included Student's t-test (for comparison of two groups, e.g. considering sex), Chi Square tests (for analyses of frequency distributions, e.g. prevalence of overweight/obesity) and ANOVA using school as the independent factor. For evaluation of the effect of the intervention, repeated measures ANOVA was applied with school as the between subjects' factor and the main target variable at FU1 and FU2 as the repeated measures factor. ANOVA was performed for the comparison of BM to FU1, and for FU1 to FU2 separately, to prevent data loss associated with school-leaving of the 4^{th} graders. Due to large pre-existing differences between the schools, data of the two intervention schools were not merged, but included separately, resulting in three groups and changes over two academic years being compared. Furthermore, and in addition to analyses of the raw data, results of the Andersen Running Test were normalized by using the relative extent of pre-existing differences between the schools applied on BM and follow-up data (see 2.7.4).

2.7.1. Blood pressure analysis

We aimed to perform blood pressure measurements three times for all children. In adherence to the guidelines by the AAP, multiple BP measurements were raised and

validated. When differences between measurements of sysBP exceeded >10mmHg, sometimes occurring e.g. during first reading due to arousal, the values of multiple representative values were averaged. Outliers exceeding two standard deviations in blood pressure change (from baseline to follow-up) were excluded from further analysis to reduce the risk of measurement errors. Specific reference values were determined for each child based on their individual age and height, both at BM and during FU1 and FU2 (Table . Children with sysBP below the 95th percentile were categorized as normotensive, when exceeding the 95th percentile identified as hypertensive.

2.7.2. Body-mass-Index analysis

The BMI was calculated by dividing the body weight in kilograms by the square of the height in meters (kg/m^2). Overweight and obesity in children were defined using percentiles from Centers for Disease Control - BMI reference curves that are specific to age and sex (Table. Children were considered overweight if their BMI was above the 90th percentile, obesity was defined as a BMI above the 95th percentile.

2.7.3. Waist-to-Height ratio analysis

The WHtR was calculated by dividing waist circumference (in centimetres) by height (in centimetres). The thresholds were categorized as followed:

Table 1 - Waist-to-Height ratio classification

Waist-to-Height ratio		
< 0.4	Underweight	Very low risk
0.4 – 0.5	Normal range	Low health risk
0.5 – 0.6	Increased risk (overweight)	Indication of abdominal obesity
> 0.6	High risk (obesity)	Greatly increased risk of cardiovascular and metabolic diseases

These thresholds are valid for both children and adults.

2.7.4. Andersen-Running test analysis

First, values of absolute running distance were analysed comparing BM to FU1 and FU1 to FU2 separately, as well all three measurements in one repeated measures ANOVA, though without the 4th graders. In a second step, running distance was normalized to mediate pre-existing differences between IS1, IS2 and CS, the factors to the school with the lowest running distance in baseline were applied to both baseline and follow-up data. This allowed analysis of distance-change adherent to the physical activity intervention.

It should be noted that children already running long distances face challenges due to physiological and psychological limits, when trying to further increase their running distance. This reduces part of the significance of these normalized values.

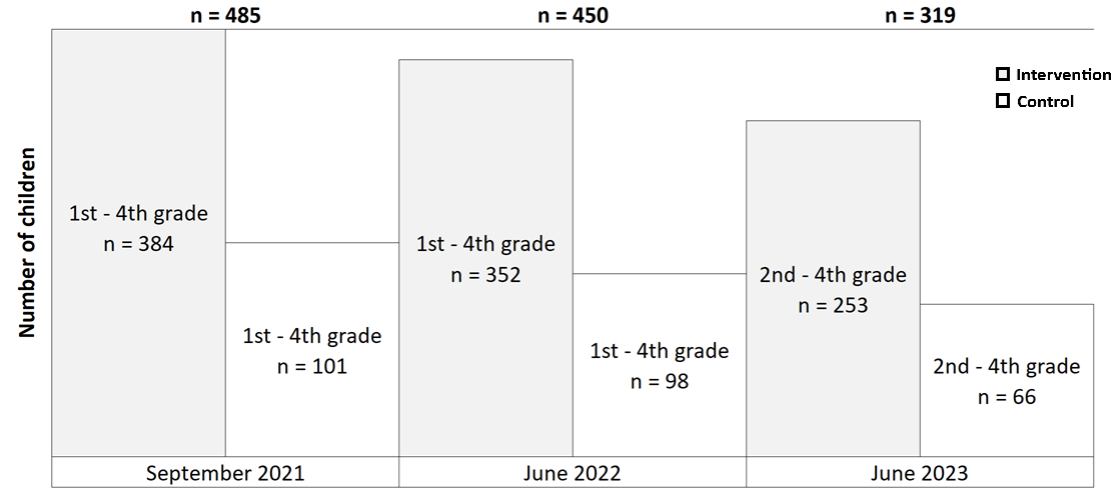
Running performance is also closely tied to physical maturity, not just aerobic fitness improvements from training. Further, children's body weight is a significant variable in predicting VO2max in the Andersen running test, where higher weight correlates with lower relative aerobic capacity (ml/kg/min). With the evaluated running distance, VO_2max can be approximated, although the formula provides higher correlation for adolescents and adults due to better pacing strategy (95):

$$VO_2max = 18.38 + (0.03301 \times \text{distance}) - (5.92 \times \text{sex [male = 0; female = 1]}).$$

3. Results

In September 2021, 485 children participated in baseline measurements (Figure 6). The study sample consisted of 53% boys and 47% girls. Children who were already in the fourth grade of elementary school at the time of the initial data collection were measured during the first follow-up in June 2022 but were lost for the second follow-up in June 2023.

Figure 6 - Study participation – Baseline, Follow-up 1 and Follow-up 2



n = number of children

3.1. Characteristics

A total of 485 children provided data, age varied from 6-11 years of age at baseline, 6-12 years old at FU1, and 7-12 years old at FU2. Distribution of mean BMI ranged from 16.1 to 18.5 at baseline, with BMI-percentiles showing that 9.8% of IS1-children, 32.6% of IS2-children and 32.3% of CS-children were overweight or obese (Table 2).

Table 2 - Study participants – Baseline characteristics

	Total (n=485)						
Variable	**IS1** (n=193)		**IS2** (n=191)		**CS** (n=101)		**statistic, p-value**
Age (years), mean (SD)	7.67	(1.17)	7.92	(1.37)	8.09	(1.38)	$F_{(2, 482)} = 3.903$, $p < 0.021$
Girls, No (%)	88	(45.6%)	88	(46.1%)	52	(51.5%)	$\chi^2_{(2)} = 1.034$, $p = 0.596$
Overweight	9	(4.9%*)	25	(13.6%*)	9	(9.7%*)	$\chi^2_{(2)} = 11.38$, $p = 0.003$
Obese	9	(4.9%*)	35	(19.0%*)	21	(22.6%*)	$\chi^2_{(2)} = 24.99$, $p < 0.001$

IS1 = Intervention school 1; IS2 Intervention school 2; CS = Control school; * children with data

Table 3 gives the mean values (± SD) of the main target variables collected at the three timepoints split by school. Children differed significantly in their height ($F_{(2, 457)} = 6.759$, $p < 0.001$), with children from IS2 being taler than children of the IS1 ($p = 0.001$), though with no difference to the CS. This finding held also for the FU1

($F_{(2, 447)}$ = 8.473, p < 0.001) and FU2 measurements ($F_{(2, 316)}$ = 7.516, p < 0.001) and might be due to the higher age in the two comparable schools IS2 and CS ($F_{(2, 482)}$ = 3.903, p = 0.021). No significant difference was found in the distribution of girls and boys between the schools ($\chi^2_{(2)}$ = 1.034, p = 0.596).

Table 3 - Summary of study results – Baseline, Follow-up 1, Follow-up 2

	Baseline			Follow Up 1			Follow Up 2		
	IS1 (n=193)	**IS2** (n=191)	**CS** (n=101)	**IS1** (n=174)	**IS2** (n=178)	**CS** (n=98)	**IS1** (n=126)	**IS2** (n=127)	**CS** (n=66)
Age	7.7 ± 1.2	7.9 ± 1.4	8.1 ± 1.4	8.3 ± 1.2	8.6 ± 1.4	8.6 ± 1.3	8.8 ± 1.0	9.0 ± 1.2	9.1 ± 1.1
Weight	28,4 ± 6.4	34.0 ± 11	33.5 ± 10	30.8 ± 7.4	37.1 ± 12	35.3 ± 9.8	32.4 ± 7.2	37.9 ± 10.3	39.2 ± 11.1
Height	1,31 ± 0.09	1.35 ± 0.11	1.34 ± 0.1	1.34 ± 0.1	1.39 ± 0.1	1.37 ± 0.1	1.37 ± 0.1	1.41 ± 0.1	1.41 ± 0.1
BMI	16,1 ± 2.0	17.6 ± 3.0	18.5 ± 3.9	16.5 ± 2.2	18.2 ± 3.3	18.6 ± 3.9	16.9 ± 2.6	18.8 ± 3.5	19.3 ± 4.0
BMI (overweight)	21.2 ± 1.7	22.7 ± 3.3	23.0 ± 3.5	21.8 ± 2.2	23.5 ± 3.3	22.8 ± 3.2	23.2 ± 2.9	22.9 ± 2.4	24.6 ± 2.9
WHtR	0.440 ± 0.031	0.464 ± 0.051	0.465 ± 0.06	0.431 ± 0.033	0.464 ± 0.055	0.462 ± 0.057	0.428 ± 0.034	0.463 ± 0.06	0.458 ± 0.054
Systolic BP	101 ± 9	105 ± 10	100 ± 11	95 ± 8	98 ± 7	94 ± 8	103 ± 8	103 ± 7	103 ± 8
Systolic BP (overweight)	110 ± 12	106 ± 10	107 ± 12	100 ± 9	102 ± 8	98 ± 10	107 ± 11	104 ± 8	107 ± 8
Andersen test	901 ± 154	836 ± 138	736 ± 109	962 ± 110	883 ± 121	736 ± 99	986 ± 115	930 ± 131	754 ± 102
Andersen test (overweight)	798 ± 173	789 ± 109	689 ± 105	845 ± 93	810 ± 112	681 ± 91	854 ± 102	856 ± 83	679 ± 88

Values are mean ± SD, n = number of participants, age in years, weight in kg, height in meters, BMI in kg/m2, systolic blood pressure in mmHg, Andersen running test in meters
IS1 = Intervention school 1; IS2 Intervention school 2; CS = Control school

3.2. Systolic blood pressure

Figure 7 shows the development of systolic BP by schools. Systolic blood pressure differed significantly between the three schools ($F_{(2, 378)}$ = 10.561, p < 0.001) and decreased from BM to FU1 ($F_{(1, 378)}$ = 157.79, p < 0.001), though there was no interaction ($F_{(2, 378)}$ = 0.238, p = 0.788). Thus, independent of the intervention, systolic BP was significantly lower at FU1 in all three schools (p < 0.001; Table 4). Children with sysBP exceeding 95th percentile were identified as hypertensive (% HTN).

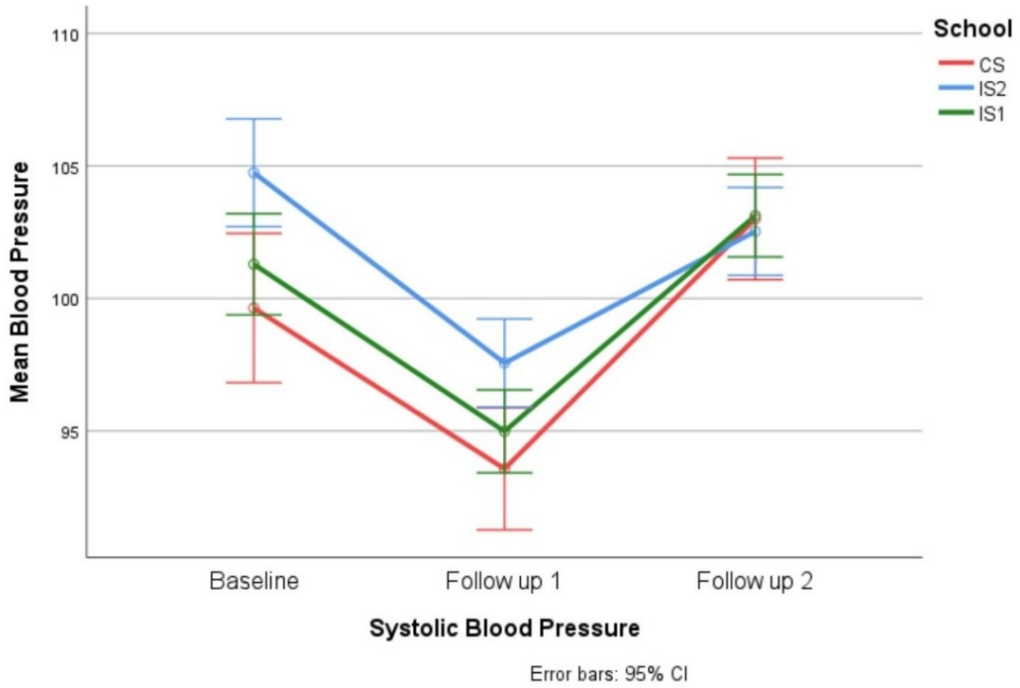
Comparison of FU1 to FU2 in contrast indicated a significant increase of systolic BP ($F_{(1, 255)}$ = 156.76, p < 0.001) and a significant interaction ($F_{(2, 255)}$ = 6.647; p < 0.001). In all three schools, systolic BP increased (p < 0.001), however in IS2 the increase was to a less degree than in the two other schools (Table 5).

Table 4 - Mean systolic blood pressure by schools and age, prevalence of hypertension

School	Age	Baseline*				Age	Follow-Up 1				Age	Follow-Up 2			
		n	mean	SD	% HTN		n	mean	SD	% HTN		n	mean	SD	% HTN
IS1		29	99	9.6	10.3		12	89	7.2	0.0		12	97	6.7	0.0
IS2	6	22	103	10.2	22.7	6	7	95	4.2	0.0	7	7	102	3.9	0.0
CS		15	95	10.8	6.7		5	95	5.0	0.0		4	100	11.1	0.0
IS1		42	101	8.5	9.5		36	94	8.0	0.0		36	103	9.4	11.1
IS2	7	35	106	9.7	17.1	7	39	99	8.0	2.6	8	39	102	7.7	2.6
CS		18	103	11.6	11.1		21	93	8.8	0.0		18	96	7.7	0.0
IS1		40	105	8.5	22.5		43	95	9.3	4.7		41	101	7.9	4.9
IS2	8	24	104	10.0	16.7	8	39	99	8.0	2.6	9	41	102	8.0	0.0
CS		19	102	13.6	15.8		19	94	10.2	10.5		19	104	8.8	5.3
IS1		35	103	8.8	5.7		47	99	7.3	2.1		34	108	6.0	2.9
IS2	9	38	105	9.0	10.5	9	35	102	9.2	5.7	10	24	103	7.8	0.0
CS		21	99	8.2	0.0		27	95	10.3	3.7		22	107	8.2	9.1
IS1		5	105	4.4	0.0		34	98	11.0	2.9		1	125	-	100.0
IS2	10	20	106	7.7	15.0	10	38	101	7.5	0.0	11	11	104	6.2	9.1
CS		13	103	9.9	7.7		21	96	10.0	0.0		2	103	5.4	0.0
IS1		-	-	-	-		1	111	-	0.0		-	-	-	-
IS2	11	3	108	8.5	33.3	11	14	103	9.6	7.1	12	3	106	7.2	0.0
CS		2	101	12.5	0.0		4	97	10.5	0.0		1	118	-	0.0
IS1							-	-	-	-					
IS2						12	2	113	24.0	50.0					
CS							1	93	-	0.0					
IS1		151	102	8.9	11.9		173	96	9.1	2.3		124	103	8.6	6.5
IS2	ALL	142	105	9.3	16.2	ALL	176	99	8.6	2.9	ALL	125	103	7.5	1.6
CS		88	101	11.0	8.0		98	95	9.5	3.1		66	103	9.4	4.6

IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; n = number of participants
mean = mean systolic blood pressure; SD = standard deviation; % HTN = Percentage above > 95th percentile systolic blood pressure norm;
*Analysis: limited to max. sysBP-change baseline to follow-up1±2SD

Figure 7 - Mean systolic blood pressure by schools



IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; mean systolic blood pressure in mmHg

Table 5 - ANOVA - Change of systolic blood pressure by schools

ALL	Timepoint	IS1 (Mean ± SD, n)	IS2 (Mean ± SD, n)	CS (Mean ± SD, n)
ANOVA 1 (n=381)	Baseline	102 ± 8.9 mmHg (n=151)	105 ± 9.3 mmHg (n=142)	101 ± 11 mmHg (n=88)
	Follow Up 1	96 ± 8.7 mmHg (n=151)	99 ± 8.4 mmHg (n=142)	95 ± 9.3 mmHg (n=88)
ANOVA 2 (n=258)	Follow Up 1	95 ± 8.5 mmHg (n=106)	98 ± 7.5 mmHg (n=93)	94 ± 9.5 mmHg (n=59)
	Follow Up 2	104 ± 8.7 mmHg (n=106)	102 ± 7.3 mmHg (n=93)	102 ± 9.5 mmHg (n=59)

IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; n = number of participants
mean = mean systolic blood pressure; ANOVA = Analysis of Variance

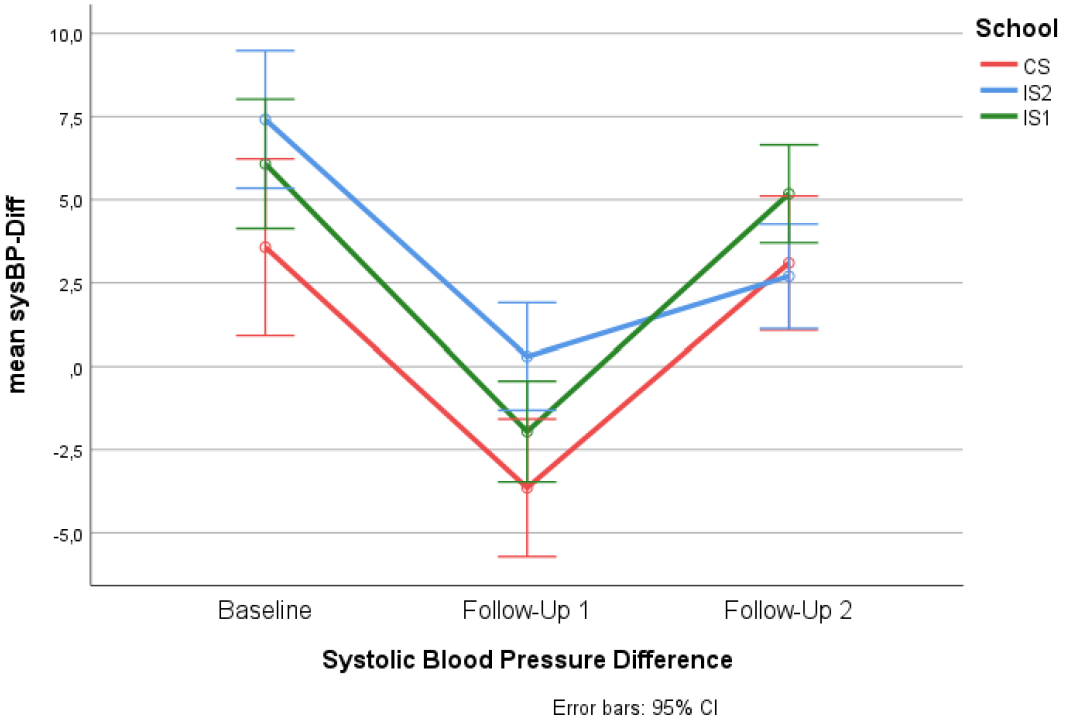
Blood pressure deviations of all study participants were determined according to specific norm BP, with differences to norm summarized in Table 6. Analysis of the deviation from the age-, height- and sex-specific normative sysBP revealed a significant main effect ($F_{(2, 397)} = 163.707$, $p < 0.001$) for the timepoint and school ($F_{(2, 397)} = 7.036$, $p < 0.001$), but no significant interaction. IS2 showed highest deviation, while in all three schools a similar and significant change showed from BM to FU1 with deviation from above the norm at BM to below norm at FU1 (Figure 8). From FU1 to FU2 sysBP deviated above norm in all three schools, as shown in the main effect ($F_{(1, 303)} = 111.129$, $p < 0.001$), though in IS2 the increase was less ($F_{(2, 303)} = 7.558$, $p < 0.001$, Table 7).

Table 6 - Mean SysBP-difference to norm of all study participants

Group	Timepoint	Mean sysBP-Diff ± SD	n
CS	Baseline	3.7 ± 11.5 mmHg	92
	Follow Up 1	-3.5 ± 9.1 mmHg	96
	Follow Up 2	3.6 ± 8.4 mmHg	65
IS1	Baseline	6.4 ± 10 mmHg	174
	Follow Up 1	-1.6 ± 8.4 mmHg	173
	Follow Up 2	5.0 ± 7.9mmHg	124
IS2	Baseline	6.5 ± 9.4 mmHg	162
	Follow Up 1	0.5 ± 8.0 mmHg	174
	Follow Up 2	3.5 ± 7.4 mmHg	123

IS= Intervention school 1 and 2; CS = Control school; n = number of participants
mean sysBP-Diff = mean systolic blood pressure difference to norm; SD = standard deviation

Figure 8 - Mean SysBP-difference to norm



IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; mean systolic blood pressure difference to norm in mmHg

Table 7 - ANOVA for mean SysBP-difference to norm by schools

ALL	Timepoint	IS1 (Mean ± SD, n)	IS2 (Mean ± SD, n)	CS (Mean ± SD, n)
ANOVA 1 (n=400)	Baseline	6.0 ± 9.9 mmHg (n=161)	6.6 ± 9.5 mmHg (n=149)	3.5 ± 11.3 mmHg (n=90)
	Follow Up 1	-1.8 ± 8.2 mmHg (n=161)	0.4 ± 8.1 mmHg (n=149)	-4.0 ± 9.0 mmHg (n=90)
ANOVA 2 (n=306)	Follow Up 1	-1.7 ± 8.2 mmHg (n=121)	0.5 ± 7.6 mmHg (n=121)	-3.2 ± 9.1 mmHg (n=64)
	Follow Up 2	5.0 ± 7.9 mmHg (n=121)	3.3 ± 7.4 mmHg (n=121)	3.5 ± 8.4 mmHg (n=64)

IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; n = number of participants
mean = mean systolic blood pressure difference to norm; ANOVA = Analysis of Variance

3.2.1. Systolic blood pressure and body mass index

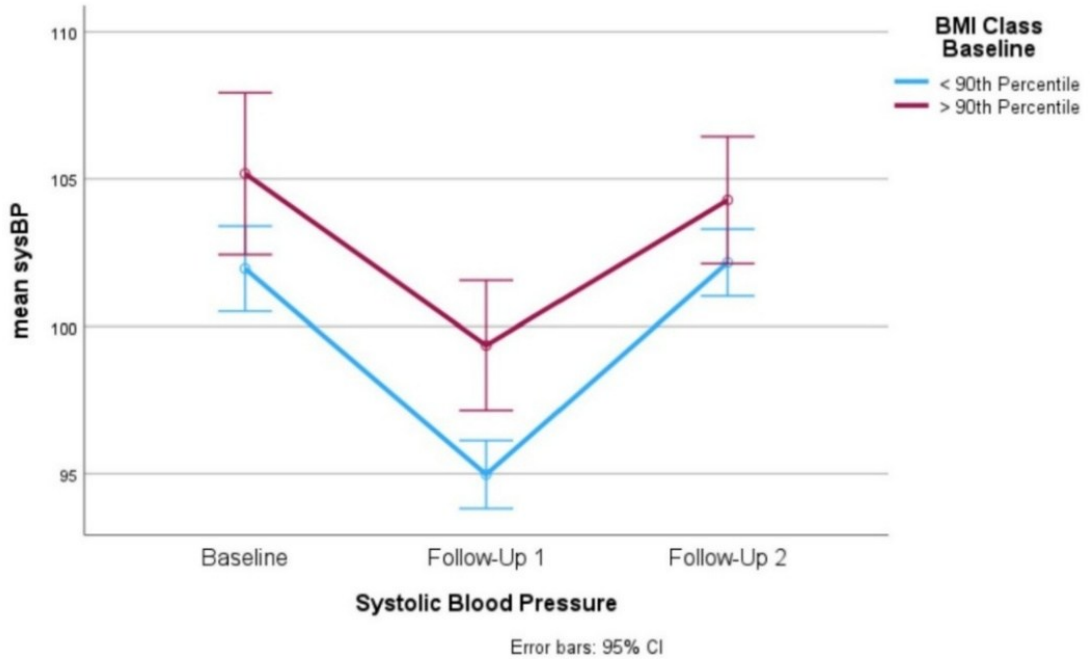
The general correlation between BMI and systolic blood pressure in elementary school-aged children was investigated (Table 8, Figure 9). Classified by the BMI (< 90th Pc), a main effect for BMI group ($F_{(1, 256)}$ = 8.461, p = 0.004) as well as for the timepoint (BM, FU1, FU2; $F_{(2, 512)}$ = 54.236, p < 0.001) was found (Table 9), though no interaction ($F_{(1, 256)}$ = 0.995, p = 0.370). The results confirm that children with overweight or obesity (> 90th Pc) had higher sysBP, the decrease at FU1 and increase of FU2 was comparable between the BMI groups.

Table 8 - Systolic blood pressure and BMI, by schools

School		Baseline*				Follow-Up 1				Follow-Up 2		
			BMI				BMI				BMI	
		n	<90th	>90th		n	<90th	>90th		n	<90th	>90th
IS1		85	103.6 (8.8)	107.9 (5.4)		98	97.8 (9.3)	102.3 (8.6)		68	104.6 (8.0)	114.6 (11.0)
IS2	male	71	105.8 (8.7)	106.4 (8.2)	male	93	98.4 (8.1)	104.3 (8.0)	male	64	103.6 (6.0)	105.6 (6.6)
CS		42	99.6 (10.4)	107.3 (14.1)		47	94.3 (9.5)	100.8 (12.0)		35	103.9 (9.5)	106.5 (7.9)
IS1		66	99.6 (8.8)	103.4 (7.5)		75	92.7 (7.9)	96.7 (8.5)		56	100.9 (8.2)	100.3 (6.8)
IS2	female	71	103.5 (9.1)	104.8 (11.4)	female	83	97.7 (9.3)	99.8 (7.4)	female	61	100.5 (8.2)	102.8 (8.7)
CS		46	97.3 (10.7)	103.4 (6.8)		51	92.3 (8.3)	95.3 (7.6)		31	97.4 (8.2)	107.4 (8.6)
IS1		151	101.9 (9.0)	106.1 (6.4)		173	95.5 (9.1)	100.0 (8.8)		124	103.0 (8.2)	107.5 (11.5)
IS2	ALL	142	104.6 (9.0)	105.6 (9.9)	ALL	176	98.0 (8.7)	102.1 (8.0)	ALL	125	102.0 (7.3)	104.3 (7.6)
CS		88	98.4 (10.5)	105.3 (10.9)		98	93.3 (8.9)	98.0 (10.2)		66	100.9 (9.4)	106.9 (8.1)

IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; n = number of participants
BMI < 90th percentile; BMI > 90th percentile; *Analysis: limited to max. sysBP-change baseline to follow-up1±2SD

Figure 9 - SysBP change of children by BMI-Class at baseline



Mean sysBP = mean systolic blood pressure in mmHg, BMI = body mass index

Table 9 - ANOVA - Systolic blood pressure by BMI - Class

Group	Timepoint	Mean sysBP ± SD	n
BMI < 90th percentile	Baseline	102 ± 10.7 mmHg	214
	Follow Up 1	95 ± 8.5 mmHg	214
	Follow Up 2	102 ± 8.2 mmHg	214
BMI ≥ 90th percentile	Baseline	105 ± 10.9 mmHg	59
	Follow Up 1	99 ± 9.0 mmHg	59
	Follow Up 2	104 ± 9.3 mmHg	59

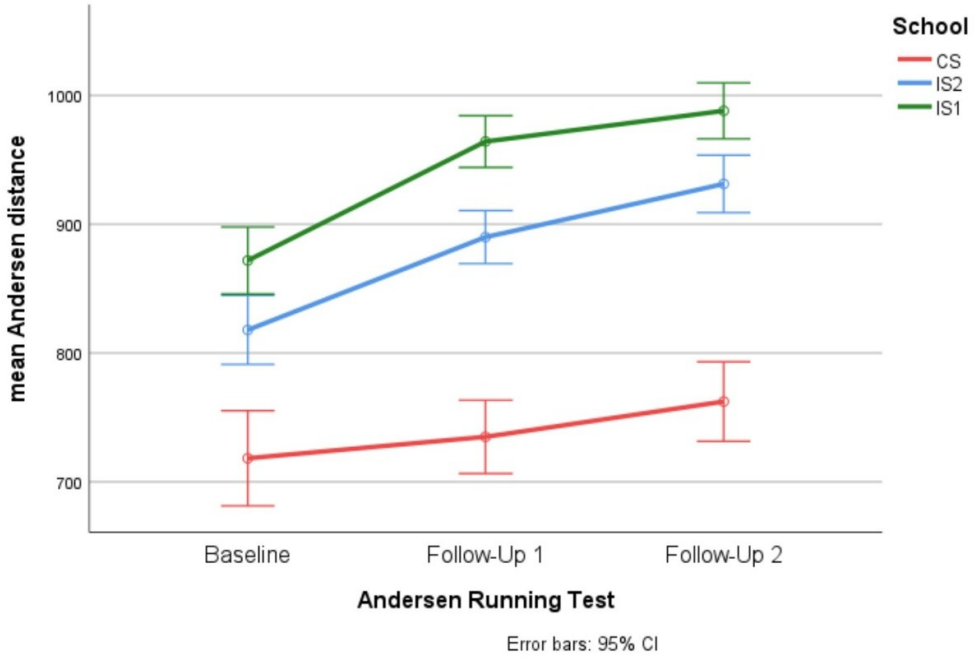
BMI = Body mass index; mean sysBP = mean systolic blood pressure; SD = standard deviation; n = number of participants

3.3. Andersen Running Test

Mean running distance covered during Andersen running test, categorized by schools, is shown in Figure 10. Results of the repeated measures ANOVA comparing the mean running distance achieved by the three schools at the three timepoints, thus without 4th graders in n=276 pupils, indicated a significant difference between the three schools ($F_{(2,\ 273)}$ = 72.948, $p < 0.001$) as well as a main effect for the measurement timepoint ($F_{(1.7,\ 472)}$ = 79.793, $p < 0.001$) and their interaction ($F_{(3.5,\ 472)}$ = 5.668, $p < 0.001$). Results were further subcategorized into male and female (Table 12, Figure 12 and Table 14, Figure 13), according to age and school. Running distance changes were analysed with ANOVA (Table 13, Table 15). Running performance differed significantly between the three schools and at all three timepoints (for all: $p < 0.001$) with IS1 showing the best performance and the CS showing the least. Furthermore, post-tests indicated a significant increase in the mean distance run from BM to FU1 and from FU1 to FU2 in the two intervention schools (for both: $p < 0.001$), while the increase in the CS was not significant.

To maximize the sample size, two additional ANOVAs were performed to compare BM to FU1, and FU1 to FU2, separately. Similar to above, the ANOVA indicated a significant interaction of school x timepoint ($F_{(2,\ 412)}$ = 8.070, $p < 0.001$) for the comparison of BM to FU1. In the enlarged sample (n= 415, 4th graders included) a significant increase in running distance was found for the two intervention schools ($p < 0.001$) , but not for the CS.

Figure 10 - Mean running distance covered during Andersen running test



IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; mean Andersen distance in metres

From FU1 to FU2 in n = 293 children, only the main effects for school ($F_{(2, 290)}$ = 95.289, p < 0.001) and timepoint ($F_{(1, 290)}$ = 35.726, p < 0.001) reached significance, but not the interaction ($F_{(2, 290)}$ = 1.676, p = 0.0189), which was due to the increase of performance also seen in the CS (Table 10).

Table 10 - ANOVA - Changes of running distance

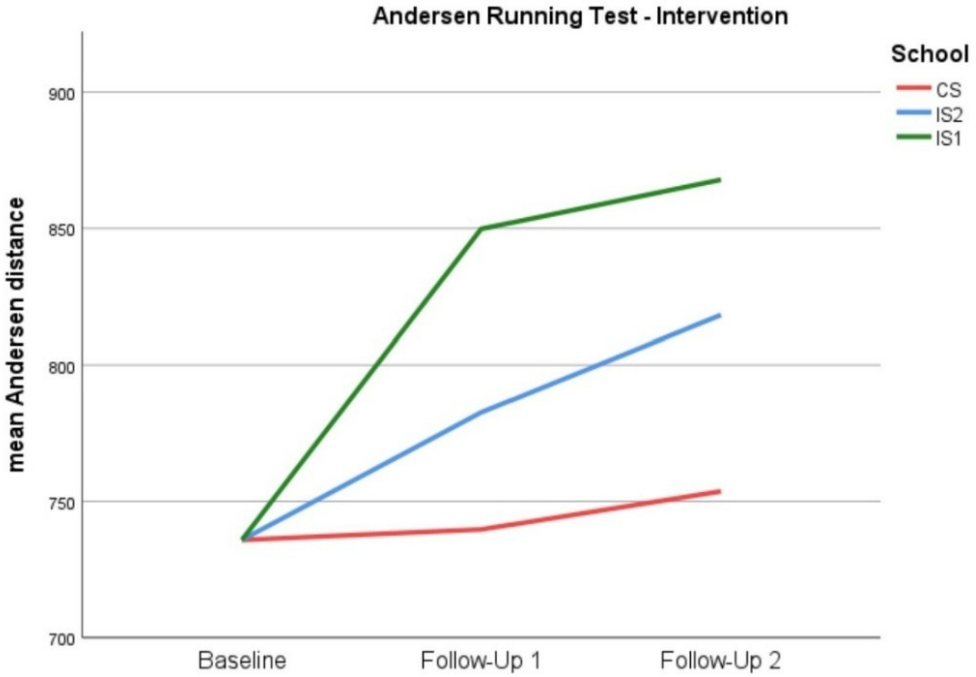
ALL	Timepoint	IS1 (Mean ± SD, n)	IS2 (Mean ± SD, n)	CS (Mean ± SD, n)
ANOVA 1 (n=415)	Baseline	896 ± 154 (n=165)	836 ± 140 (n=163)	736 ± 111 (n=87)
	Follow Up 1	965 ± 107 (n=165)	889 ± 115 (n=163)	740 ± 98 (n=87)
ANOVA 2 (n=293)	Follow Up 1	962 ± 106 (n=116)	882 ± 121 (n=116)	727 ± 106 (n=61)
	Follow Up 2	986 ± 116 (n=116)	928 ± 133 (n=116)	757 ± 98 (n=61)

IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; n = number of participants
mean = mean Andersen running test distance, ANOVA = Analysis of Variance

To illustrate the change in running distance regarding the intervention, initial differences at BM were factored out (Figure 11, Table 11) and ANOVA performed, subtracting baseline differences, and maintained for FU1 and FU2 distances. Running performance increased significantly from BM to FU1 ($F_{(2, 412)}$ = 32.697, p < 0.001) in IS1 and IS2 (both: p < 0.001)

but not in the CS. For FU1 to FU2 the interaction however failed significance ($F_{(2, 290)} = 1.513$, $p = 0.222$) due to a larger increase in the CS as compared to IS 1.

Figure 11 - Normalized relative running distance



IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; normalized mean Andersen distance in meters

Table 11 - ANOVA - Relative change of running distance

Group	Timepoint	Mean ± SD	n
CS	Baseline	736 ± 111	87
	Follow Up 1	740 ± 98	87
	Follow Up 2	754 ± 102	65
IS 1	Baseline	736 ± 127	165
	Follow Up 1	850 ± 95	165
	Follow Up 2	868 ± 101	121
IS 2	Baseline	736 ± 123	163
	Follow Up 1	783 ± 101	163
	Follow Up 2	818 ± 116	120

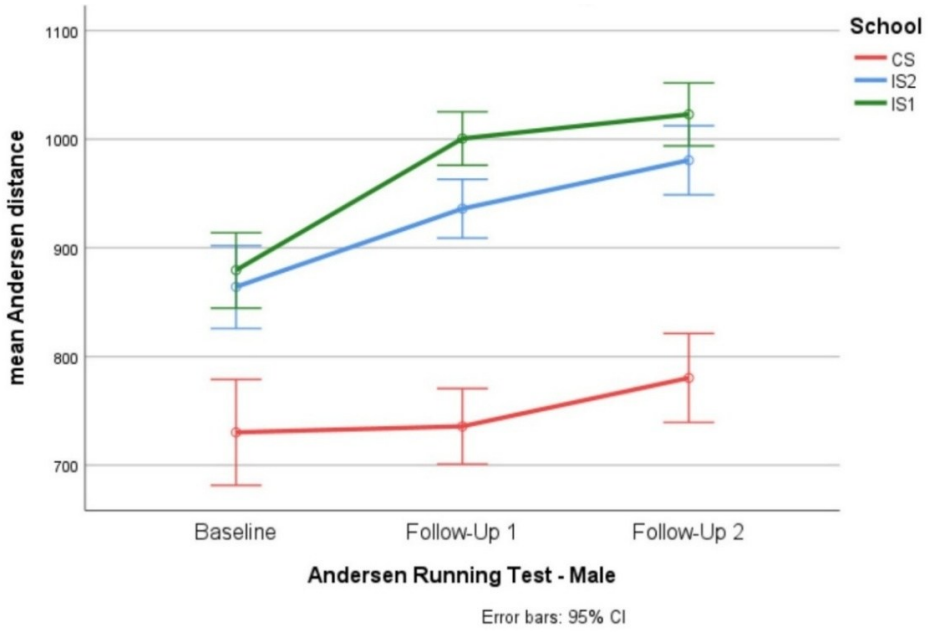
CS = Control school; IS1= Intervention school 1 ; IS2 = Intervention school 2; ; n = number of participants
Mean = mean Andersen running distance in meters; SD = standard deviation

Table 12 - Andersen running test distances by school and age – male participants

Male	Age	Baseline			Age	Follow-Up 1			Age	Follow-Up 2		
School		n	mean	SD		n	mean	SD		n	mean	SD
IS1		18	796	140		6	960	76		1	744	-
IS2	6	14	847	133	6	4	886	143	7	4	863	164
CS		7	714	61		3	741	36		2	760	4
IS1		21	905	142		19	960	89		19	997	101
IS2	7	21	845	101	7	20	904	108	8	17	966	138
CS		9	752	69		9	760	115		8	809	82
IS1		29	937	162		21	988	96		19	973	137
IS2	8	13	860	187	8	18	924	99	9	20	974	142
CS		15	735	128		8	730	98		9	726	143
IS1		23	950	146		27	1045	93		24	1083	90
IS2	9	26	873	154	9	16	936	89	10	10	1006	114
CS		8	755	169		16	736	153		15	780	132
IS1		5	1078	80		21	1002	111		1	830	-
IS2	10	14	925	150	10	24	879	150	11	9	974	133
CS		5	840	44		8	783	47		1	744	-
IS1		-	-	-		1	980	-		-	-	-
IS2	11	1	1020	-	11	9	961	115	12	2	1043	28
CS		1	723	-		1	865	-		-	-	-
IS1						-	-	-				
IS2					12	1	1005	-				
CS						1	728	-				

IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; n = number of participants
mean = mean Andersen running test distance

Figure 12 - Mean running distance covered - by school, male participants



IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; normalized mean Andersen distance in meters

Table 13 - Changes of running distance of male participants

Male	Timepoint	IS1 (Mean ± SD, n)	IS2 (Mean ± SD, n)	CS (Mean ± SD, n)
ANOVA 1 (n=218)	Baseline	909 ± 160 (n=91)	872 ± 146 (n=84)	750 ± 115 (n=43)
	Follow Up 1	1003 ± 99 (n=91)	927 ± 101 (n=84)	750 ± 115 (n=43)
ANOVA 2 (n=159)	Follow Up 1	998 ± 95 (n=66)	918 ± 114 (n=60)	733 ± 126 (n=33)
	Follow Up 2	1018 ± 116 (n=66)	970 ± 136 (n=60)	778 ± 112 (n=33)

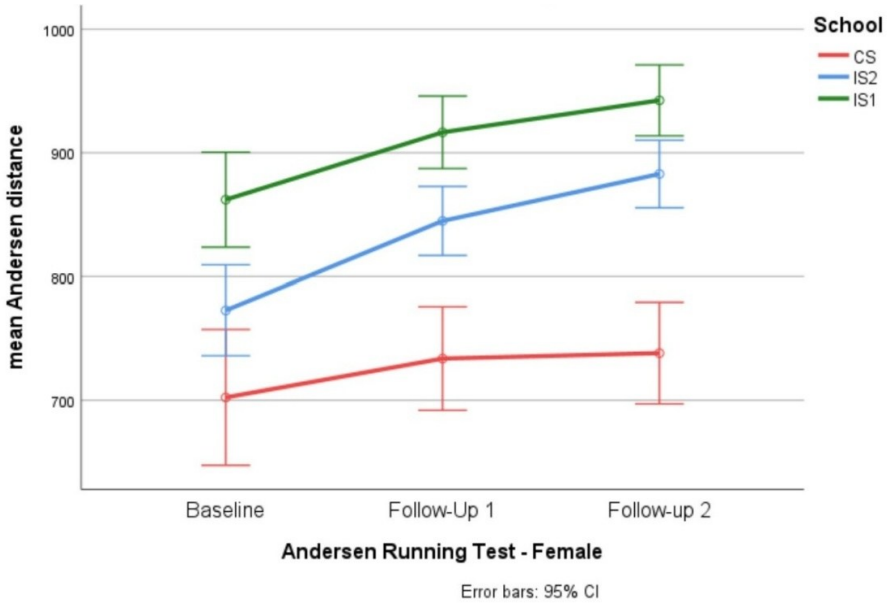
IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; n = number of participants
mean = mean Andersen running test distance, ANOVA = Analysis of Variance

Table 14 - Andersen running test distances by school and age – female participants

Female	Age	Baseline			Age	Follow-Up 1			Age	Follow-Up 2		
School		n	mean	SD		n	mean	SD		n	mean	SD
IS1		16	811	109		6	891	76		6	909	106
IS2	6	15	742	118	6	3	795	102	7	2	885	92
CS		7	678	106		2	666	88		2	637	61
IS1		28	889	103		18	877	129		17	892	126
IS2	7	23	799	98	7	22	789	116	8	20	830	131
CS		10	760	50		12	707	73		10	685	50
IS1		18	950	188		22	939	69		21	974	52
IS2	8	14	781	121	8	19	899	111	9	20	925	100
CS		5	748	133		9	765	66		10	789	66
IS1		16	888	172		18	950	91		9	983	84
IS2	9	22	820	138	9	17	847	113	10	13	887	77
CS		14	691	106		9	698	83		6	744	59
IS1		1	925	-		12	887	131		-	-	-
IS2	10	7	884	118	10	14	866	108	11	2	897	9
CS		9	750	128		13	735	77		1	760	-
IS1		-	-	-		-	-	-		-	-	-
IS2	11	2	867	23	11	6	891	94	12	1	1072	-
CS		1	740	-		3	705	155		1	775	-
IS1						-	-	-				
IS2					12	1	870	-				
CS						-	-	-				

IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; n = number of participants
mean = mean Andersen running test distance

Figure 13 - Mean running distance covered - by school, female participants



IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; normalized mean Andersen distance in meters

Table 15 - Changes of running distance of female participants

Female	Timepoint	IS1 (Mean ± SD, n)	IS2 (Mean ± SD, n)	CS (Mean ± SD, n)
ANOVA 1 (n=197)	Baseline	880 ± 147 (n=74)	798 ± 122 (n=79)	722 ± 107 (n=44)
	Follow Up 1	920 ± 100 (n=74)	849 ± 116 (n=79)	730 ± 78 (n=44)
ANOVA 2 (n=134)	Follow Up 1	914 ± 101 (n=50)	843 ± 117 (n=56)	719 ± 78 (n=28)
	Follow Up 2	943 ± 101 (n=50)	882 ± 114 (n=56)	732 ± 74 (n=28)

IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; n = number of participants
mean = mean Andersen running test distance, ANOVA = Analysis of Variance

3.3.1. Distance in relation to Norwegian Reference Data

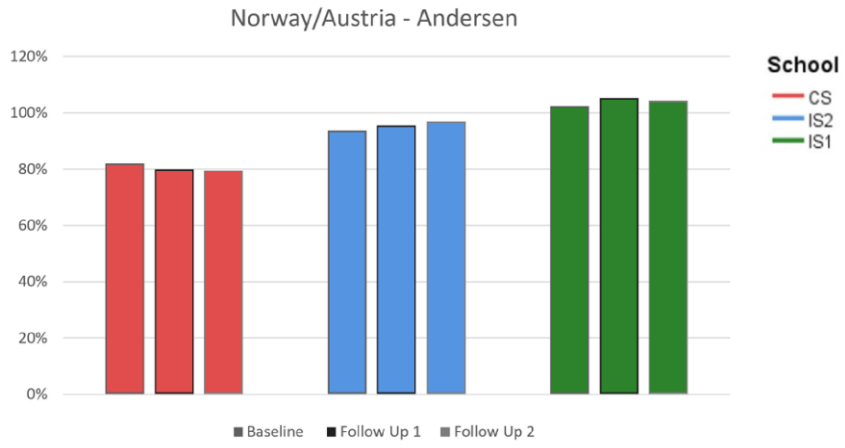
Comparison of the running performance of the three schools to reference values determined within the Norwegian HOPP study (96) indicated that children of two schools (IS2 and CS) showed markedly lower performance, while performance of IS1-children remained high (Figure 14). As shown in Table 10, children of the intervention schools increased their performance, IS1 improved from 102.4% to 104.2% and IS2 from 93.7% to 97.0% of the Norwegian norm, but CS fell from 82.1% to 79.6%.

Table 16 - Andersen Test - Running distance - Norwegian reference values

Age	n	Mean	SD	Percentiles						
Male				**5**	**10**	**25**	**50**	**75**	**90**	**95**
6	104	792	109	601	635	726	802	860	937	978
7	145	844	118	643	720	783	850	915	985	1029
8	160	944	122	765	785	860	945	1024	1080	1158
9	185	971	131	771	793	890	975	1060	1143	1179
10	166	1010	124	819	849	914	1020	1105	1165	1208
11	188	1036	113	832	880	954	1043	1120	1181	1206
12	69	1091	104	878	960	1013	1095	1188	1220	1235
Female										
6	97	757	114	550	594	688	765	828	892	936
7	141	835	107	636	680	778	840	915	970	990
8	161	908	118	716	768	840	905	975	1050	1095
9	168	936	122	738	795	870	940	1020	1061	1129
10	175	964	104	796	860	905	960	1020	1094	1145
11	188	988	107	802	835	930	1000	1050	1123	1153
12	63	1077	104	940	947	1025	1075	1140	1211	1228

n = number of participants; Source: Factors affecting running performance in 6–12-year-olds: The Health Oriented Pedagogical Project (HOPP) – Table II (96)

Figure 14 - Mean running distance in reference to Norwegian standard values



CS = Control school; IS2 = Intervention school 2; IS1 = Intervention school 1

Table 17 - Mean running distance in reference to Norwegian standard values

Group	Timepoint	%	n
CS	Baseline	82,1%	91
	Follow Up 1	80,0%	94
	Follow Up 2	79,6%	53
IS 1	Baseline	102,4%	175
	Follow Up 1	105,1%	171
	Follow Up 2	104,2%	105
IS 2	Baseline	93,7%	172
	Follow Up 1	95,4%	174
	Follow Up 2	97,0%	103

CS = Control school; IS1= Intervention school 1 ; IS2 = Intervention school 2; ; n = number of participants
% = Mean percentage of Norwegian standard values for Andersen running distance

3.4. Body Mass Index (BMI)

BMI of 460 children was calculated and categorized into age-related percentiles. At baseline measurements 23.5% of all children were overweight or obese, 14.1% of children had obesity. School differences at BM are displayed in Figure 15, showing an uneven distribution of BMI-percentiles, with CS and IS2 having more similar BMI-distribution. Baseline BMI (BMI-SDS) differed significantly between the schools ($F_{(2,\ 457)}$ = 21.564, $p < 0.001$) with IS1 showing the least mean BMI of 16.4 (SD ±2.1), and IS2 and CS more similar mean BMIs of 18.4 (SD ±3.8) and 18.5 (SD ±4.0), respectively.

Repeated measures ANOVA comparing BM to FU1 revealed a significant main effect for the BMI change ($F_{(1,\ 432)}$ = 70.436, $p < 0.001$) as well as for the interaction with school ($F_{(2,\ 432)}$ = 9.577, $p < 0.001$, Figure 15). Post-hoc comparisons indicated a significant increase of BMI in IS1 ($p < 0.001$) and IS2 ($p < 0.001$), but not in the CS ($p = 0.149$).

For analysis of FU1 to FU2 (without 4th graders), also a main effect for BMI change was found ($F_{(2,\ 311)}$ = 105.274, $p < 0.001$) whilst the interaction with school shortly failed significance ($F_{(2,\ 311)}$ = 2.884, $p = 0.057$). In all three schools BMI increased significantly ($p < 0.001$) from FU1 to FU2 (Table 17, Figure 16), though the mean increase was smaller in the two intervention schools (mean BMI difference IS1: + 0.440, IS2: + 0.629) as compared to the CS (mean BMI difference: + 0.812).

Figure 15 - BMI percentiles at baseline measurement

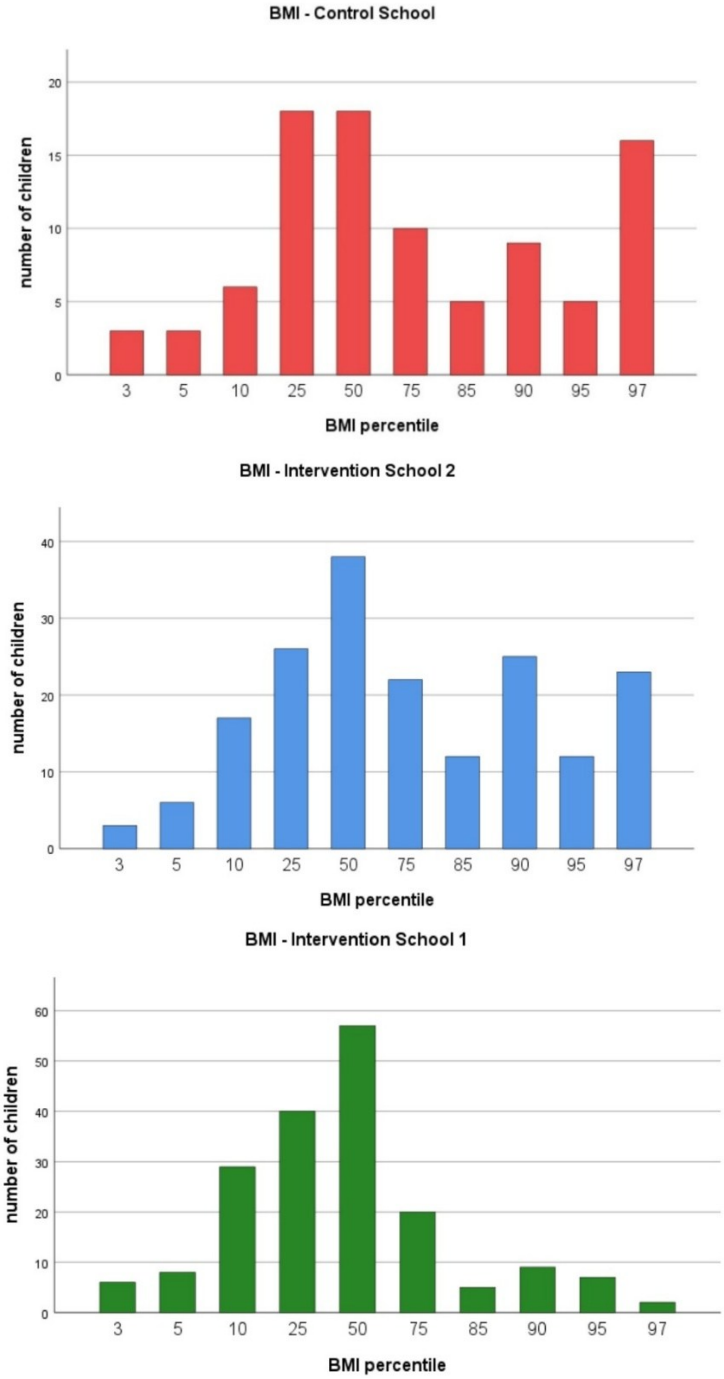


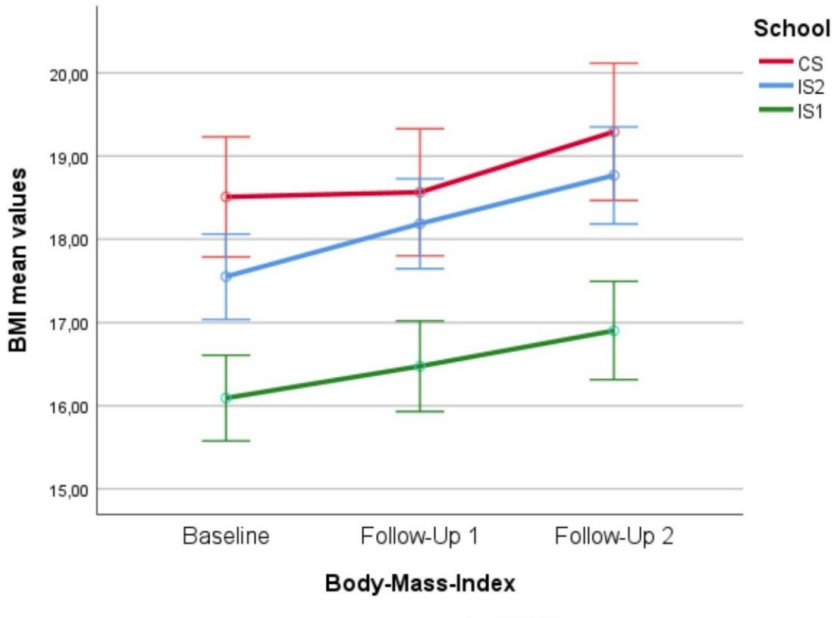
Table 18 - BMI by school, age and measurement time

School	Age	Baseline			Age	Follow-Up 1			Age	Follow-Up 2		
		n	>90th	%		n	>90th	%		n	>90th	%
IS1		34	3	8.8		12	2	16.7		12	0	0.0
IS2	6	34	9	26.5	6	7	2	28.6	7	7	3	42.9
CS		15	6	40.0		5	4	80.0		4	3	75.0
IS1		51	6	11.8		37	5	13.5		37	5	13.5
IS2	7	46	10	21.7	7	42	8	19.0	8	39	9	23.1
CS		19	4	21.1		21	4	19.0		18	3	16.7
IS1		48	0	0.0		43	4	9.3		41	4	9.8
IS2	8	30	10	33.3	8	39	13	33.3	9	41	13	31.7
CS		20	8	40.0		19	4	21.1		19	5	26.3
IS1		42	8	19.0		47	2	4.3		35	1	2.9
IS2	9	48	19	39.6	9	35	12	34.3	10	25	11	44.0
CS		23	8	34.8		27	11	40.7		22	8	36.4
IS1		8	1	12.5		34	7	20.6		1	0	0.0
IS2	10	23	11	47.8	10	38	14	36.8	11	12	4	33.3
CS		14	4	28.6		21	4	19.0		2	1	50.0
IS1		-	-	-		1	0	0.0		-	-	-
IS2	11	3	1	33.3	11	15	6	40.0	12	3	0	0.0
CS		2	0	0.0		4	2	50.0		1	0	0.0
IS1						-	-	-				
IS2					12	2	1	50.0				
CS						4	2	50.0				
IS1		183	18	9.8		174	20	11.5		126	10	7.9
IS2	ALL	184	60	32.6	ALL	178	56	31.5	ALL	127	40	31.5
CS		93	30	32.3		101	31	30.7		66	20	30.3

IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; n = number of participants
BMI > 90th percentile; % = Percentage above > 90th BMI percentile

Figure 16 illustrates the change in BMI from BM to FU1 and FU2, showing largest differences due to school affiliation, while rising physiologically during children's growth. Table 19 highlights persistence of initial school differences in the distribution of individual BMI percentiles at all three measurement points, baseline, FU1 and FU2.

Figure 16 - Mean BMI change by school



IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; BMI mean values in kg/m²; CI = confidence interval

Table 19 - BMI percentiles by school

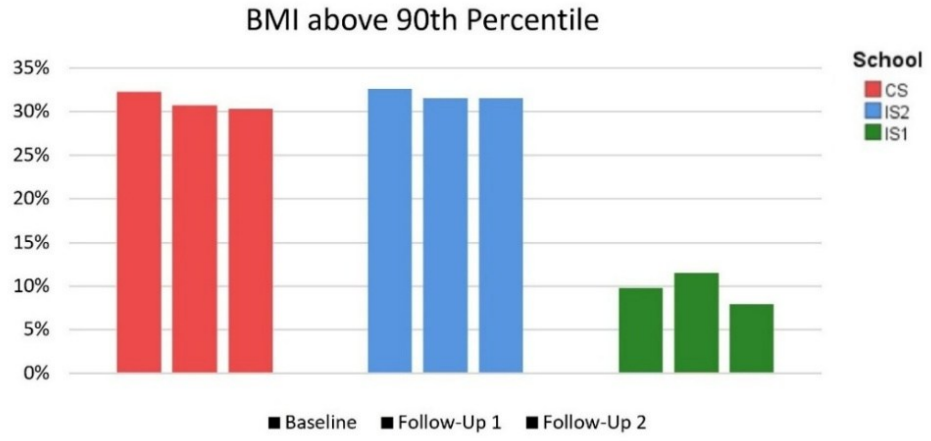
BMI Percentile	IS1 (n=183)			IS2 (n=184)			CS (n=93)		
	Baseline	Follow-Up 1	Follow-Up 2	Baseline	Follow-Up 1	Follow-Up 2	Baseline	Follow-Up 1	Follow-Up 2
3	3%	4%	4%	2%	4%	4%	3%	0%	0%
5	4%	3%	3%	3%	2%	2%	3%	3%	5%
10	16%	15%	14%	9%	9%	9%	6%	11%	8%
25	22%	25%	25%	14%	14%	14%	19%	20%	12%
50	31%	28%	26%	21%	19%	23%	19%	20%	21%
75	11%	7%	12%	12%	12%	11%	11%	8%	11%
85	3%	6%	6%	7%	9%	6%	5%	7%	12%
90	5%	6%	3%	14%	10%	11%	10%	10%	5%
95	4%	3%	2%	7%	7%	9%	5%	7%	6%
97	1%	2%	3%	13%	15%	12%	17%	12%	21%

IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; n = number of participants; BMI = body mass index

3.4.1. BMI change – Overweight and obese children

The percentage of children classified as being overweight or obese based on their age- and sex-specific percentile at the three measurements timepoints is shown in Figure 17. IS1 had a significantly lower number of children with overweight or obesity ($\chi^2_{(2)}$ = 31.485, $p < 0.001$) as compared to both other schools at baseline, however at FU1 their number increased whilst it decreased in the CS and the IS2 ($\chi^2_{(2)}$ = 20.910, $p < 0.001$).

Figure 17 - Percentage of overweight or obese children by school



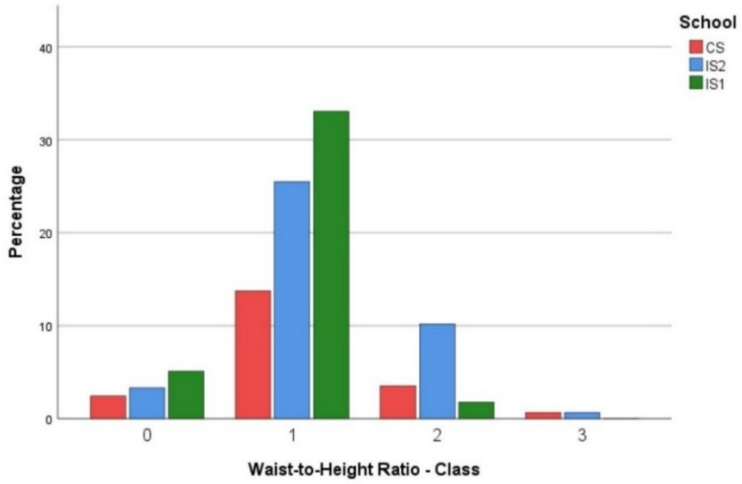
IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school

3.5. Waist-to-Height Ratio (WHtR)

Waist-to-Height Ratio of 451 children was calculated and categorized. WHtR classification across the schools at baseline indicated significant differences ($\chi^2_{(6)}$ = 37.885, $p < 0.001$). At baseline measurements 10.9% of the total sample had WHtR beneath 0.4, the majority of

children with 72.2% were between WHtR 0.4 and 0.5. About 15.5% of children had elevated risk between WHtR 0.5 and 0.6, 1.3% were already in the high-risk group with a WHtR above 0.6. As shown in Figure 17, a larger proportion of children of IS2 and the CS were above the critical value of WHtR = 0.6 and higher.

Figure 18 - WHtR-class distribution at baseline measurement



IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school

WHtR of the children by age, school and timepoints is summarized in Table 20. Differences of IS1 to IS2 and CS remain, thus confirm the differences that emerged in the distribution of BMI percentiles.

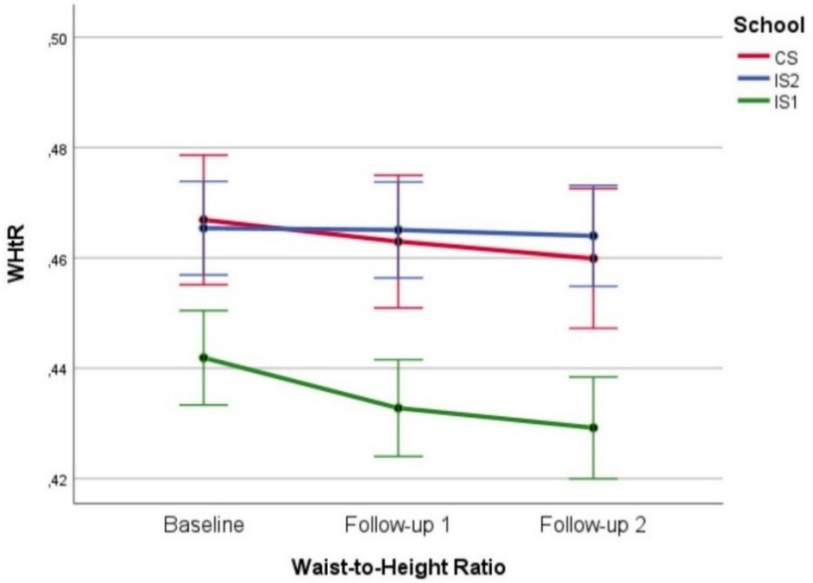
Table 20 - WHtR by school, age, waist-to-height-ratio > 0.5

School	Age	Baseline			Age	Follow-Up 1			Age	Follow-Up 2		
		n	>0.5	%		n	>0.5	%		n	>0.5	%
IS1		33	0	0.0		12	1	8.3		12	0	0.0
IS2	6	32	7	21.9	6	7	2	28.6	7	6	2	33.3
CS		14	5	35.7		5	4	80.0		4	2	50.0
IS1		49	3	6.1		36	3	8.3		37	6	16.2
IS2	7	46	8	17.4	7	42	6	14.3	8	37	5	13.5
CS		19	2	10.5		21	1	4.8		18	3	16.7
IS1		48	0	0.0		43	1	2.3		39	2	5.1
IS2	8	29	6	20.7	8	39	6	15.4	9	40	12	30.0
CS		20	5	25.0		19	3	15.8		19	3	15.8
IS1		42	4	9.5		46	0	0.0		33	0	0.0
IS2	9	47	18	38.3	9	35	10	28.6	10	25	8	32.0
CS		23	4	17.4		27	8	29.6		22	6	27.3
IS1		8	1	12.5		34	4	11.8		1	1	100.0
IS2	10	22	9	40.9	10	38	14	36.8	11	12	4	33.3
CS		14	3	21.4		21	5	23.8		2	1	50.0
IS1		-	-	-		1	0	0.0		-	-	-
IS2	11	3	1	33.3	11	14	4	28.6	12	3	0	0.0
CS		2	0	0.0		4	1	25.0		1	1	100.0
IS1						-	-	-				
IS2					12	2	0	0.0				
CS						1	0	0.0				
IS1		180	8	4.4		172	9	5.2		122	9	7.4
IS2	ALL	179	49	27.4	ALL	177	42	23.7	ALL	123	31	25.2
CS		92	19	20.7		98	22	22.4		66	16	24.2

IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; n = number of participants
WHtR > 0.5; % = Percentage above WHtR > 0.5

WHtR changed significantly from BM to FU1 ($F_{(2,\ 425)}$ = 9.092, p = 0.003), while the significant interaction with school ($F_{(2,\ 425)}$ = 6.527, p = 0.002) was mainly due to a decrease of WHtR in IS1 (mean WHtR baseline = 0.437 vs. mean WHtR FU1 = 0.428, p < 0.001) in contrast to an non-significant decrease in IS2 (p = 0.650) and the CS (p = 0.775).

Figure 19 - Mean WHtR by school



IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; Error bars 95% CI; WHtR = waist-to-height ratio

Repeated measures ANOVA for comparison of FU1 to FU2 in contrast showed neither a main effect for the timepoint ($F_{(2,\ 303)}$ = 1.966, p = 0.162) nor an interaction with school and therewith the intervention ($F_{(2,\ 303)}$ = 0.667, p = 0.514). The main effect for school, with IS 1 having the lowest WHtR also remained significant ($F_{(2,\ 303)}$ = 15.247, p < 0.001).

Overall, there were only modest changes in WHtR in both intervention schools and the control school, biggest differences were due to school affiliation. Across all schools WHtR above 0.5 increased from 16.8% at BM up to 18% of children at FU2 (Table 20, Figure 20), while mean WHtR-values decreased (Figure 19).

Figure 20 - WHtR-class change by school

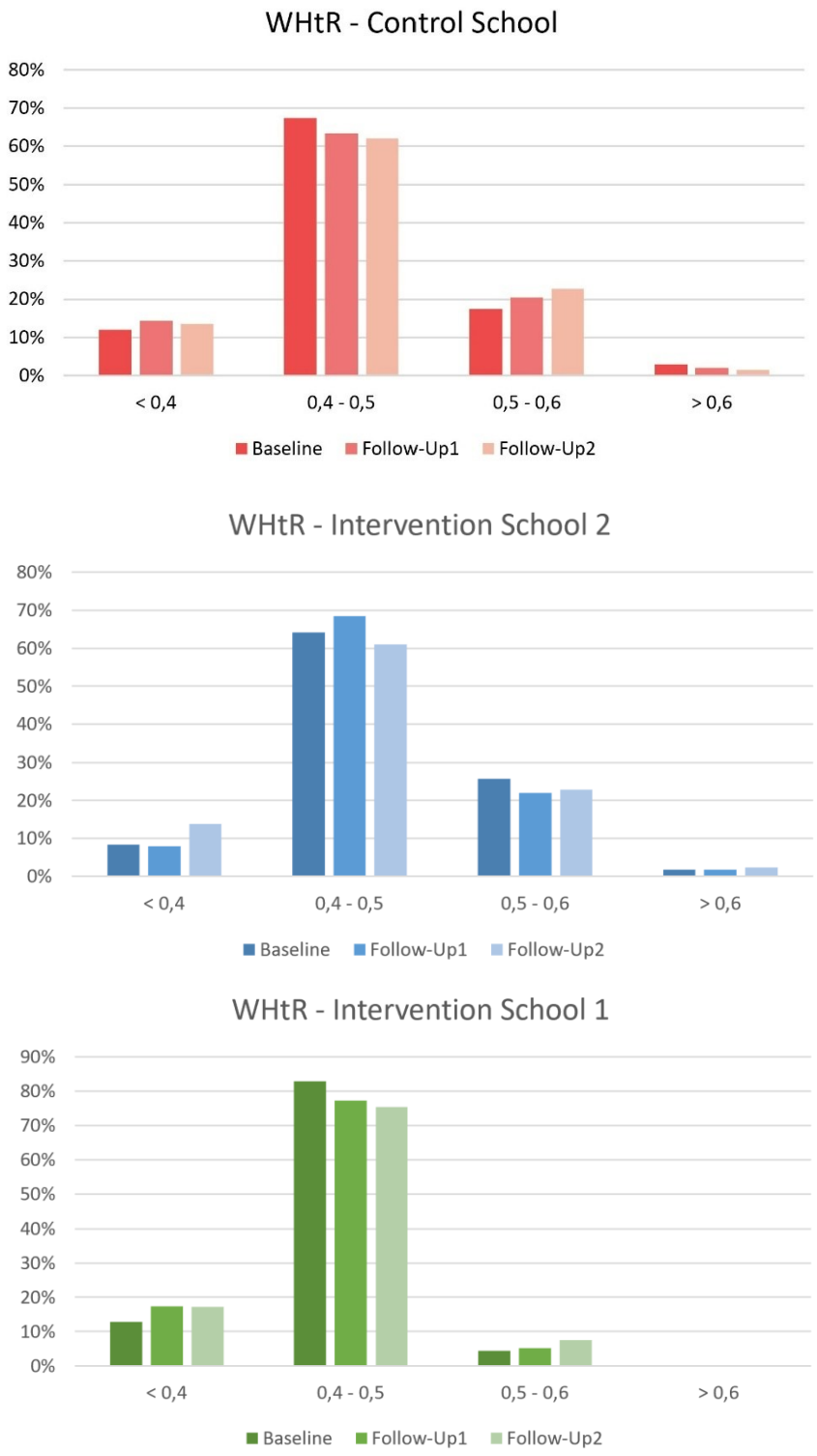


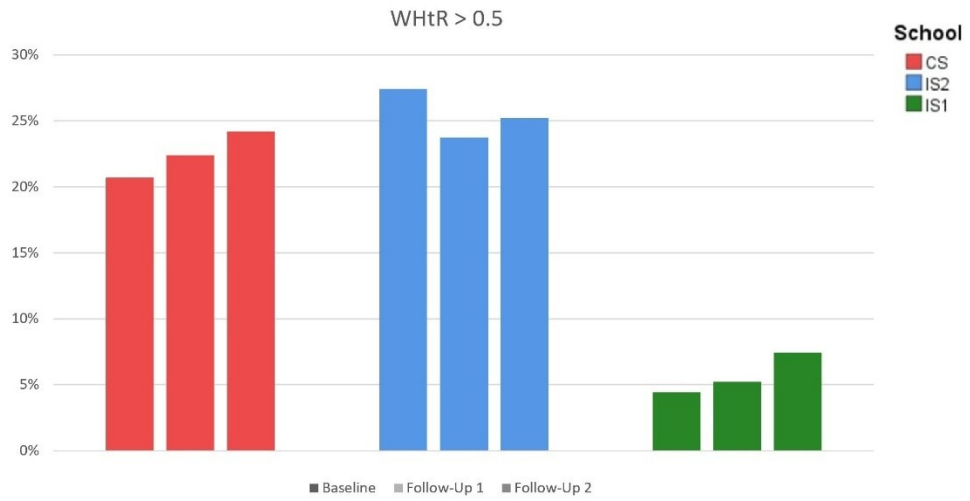
Table 21 - Waist-to-height ratio classification

Group	WHtR	Baseline	Follow-Up 1	Follow-Up 2
CS	< 0.4	12.0%	14.3%	13.6%
	0.4 – 0.5	67.4%	63.3%	62.1%
	0.5 – 0.6	17.4%	20.4%	22.7%
	> 0.6	3.0%	2.0%	1.5%
IS2	< 0.4	8.4%	7.9%	13.8%
	0.4 – 0.5	64.2%	68.4%	61.0%
	0.5 – 0.6	25.7%	22.0%	22.8%
	> 0.6	1.7%	1.7%	2.4%
IS1	< 0.4	12.8%	17.4%	17.2%
	0.4 – 0.5	82.8%	77.3%	75.4%
	0.5 – 0.6	4.4%	5.2%	7.4%
	> 0.6	0.0%	0.0%	0.0%

IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school; WHtR = Waist-to-height ratio

In Figure 21 WHtR above 0.5, categorized by school, is displayed. At baseline IS1 showed significantly lower proportion of children with elevated WHtR suggesting abdominal adiposity than IS2 and CS, exceeding 25% and 20% respectively. Children from IS2 showed a reduction of affected children, IS1 an increase from 4.4% to 7.4% with elevated WHtR (Table 21).

Figure 21 - Children with WHtR > 0.5 by school



IS1 = Intervention school 1; IS2 = Intervention school 2; CS = Control school

4. Discussion

This thesis investigated the effect of a daily PA intervention in the form of active learning on cardiovascular and metabolic health of 485 primary school children in Austria. For CV health data of systolic blood pressure and running distance in the Andersen running test, for metabolic health data of BMI and WHtR was gathered and analysed.

4.1. Main findings

4.1.1. Systolic blood pressure

Systolic blood pressure differed significantly between the three schools, ranging from 105mmHg ±9.3mmHg in IS2, and 102mmHg ±8.9mmHg in IS1 to 101mmHg ±11mmHg in CS (Table 4, Figure 7). Change occurred in reference to sex-, age- and height- specific BP norms (Table 22, Table 23) from +6.6mmHg above norm to +0.4mmHg above norm in IS2 from BM to FU1. Similar reduction of systolic blood pressure to norm were found for IS1, from +6.0mmHg to -1.8mmHg, and for CS, from +3.5mmHg to -4.0mmHg. Unfortunately baseline blood pressure measurements where highly impacted by arousal, despite best BP measurement practices. This made it difficult to distinguish how much reduction in systolic blood pressure was achieved by the PA intervention and how much sysBP increase at baseline was merely attributable to excitement at BM. From FU1 to FU2 the intervention seemed to mitigate effects of physiological growth-dependent blood pressure increase in IS2, showing just little increase from +0.5mmHg to +3.3mmHg in reference to norm, in contrast to sysBP increase in IS1 and CS (Figure 8). Regardless of the intervention, our study confirmed that children with BMI above 90th percentile have higher sysBP than children in normal weight range (Table 3, Table 8, Table 9, Figure 9). There were small indications that children who had hypertension at baseline could have benefited from the intervention with an additional 4mmHg mean sysBP-reduction, but the number of the examined participants reduced to 47 children, limiting results significance and leave scope for potential of further investigations of hypertensive children.

4.1.2. Endurance - Andersen Running Test

Running performance differed significantly between the three schools and at all three timepoints (Figure 10), with IS1 showing the best performance, at BM with mean running distance of 896 meters, increasing up to 986 meters at FU2. Similar, IS2 was able to

improve, from mean 836 meters at BM, to 928 meters at FU2. CS starting with least covered distance of mean 736 meters at BM, showed only small changes up to 757 meters in FU2 (Table 10). Differences between male and female students were also apparent: on the one hand, the differences between schools were more pronounced among male students (Table 13, Table 15), and on the other hand, the running distance changed to varying extent at different time points (Figure 12, Figure 13). Main predictor of baseline endurance and therefore absolute running distance was school affiliation. While children of IS1 met Norwegian norms at all three examinations, IS2 and CS were not covering norm distances at any given time (Table 17). The most striking finding here was that children from CS could only achieve 80% of the standard values and that their performance declined over time, whereas the children from IS2 with intervention gradually improved to 97% of norm and IS1 maintained their indicator of high endurance at 104% of norm (Figure 14). This demonstrates the effectiveness of a daily PA intervention in improving running performance on the one hand, but also suggests that, similar to CS, schools that did not opt for the intervention may have significantly poorer endurance performance than schools that are motivated to promote more PA in everyday schooling. This underscores the urgent need for trained sports scientists and teachers to test the fitness levels of elementary school children across Austria, compare the gathered data and search for implementable solutions. Regarding prevention, especially children without a sport club membership could benefit from daily PA during school hours (97).

4.1.3. Body Mass Index

Age-related BMI-percentiles indicate that 23.5% of Austrian primary school children in 2021 were overweight, with 14.1% already affected by obesity, having distinct difficulties maintaining a body weight within normal range. Figure 15 illustrates large differences of the occurrence of different BMI percentiles at baseline, with IS2 and CS having more similar distributions than IS1. The rate of obesity was exceeding 30% in both IS2 and CS, while IS1 remained near the 10% range for all three measurement points. The rise in mean BMI (Figure 16; partly due to children's growth) was less pronounced in the intervention schools from FU1 to FU2 (IS1 + 0.440, IS2: + 0.629, CS + 0.812). Table 19 shows while from baseline to FU1 and FU2, BMI-percentiles of ≥ 90^{th} stayed low in IS1, they remained high in

IS2 and CS (Figure 17). These elevated numbers of BMI give reason for concern, with children facing risk for negative health outcomes for years to come (Figure 3, Chapter 1.4.5). One in five children have an increased risk for future cardiovascular and metabolic disease such as hypertension and T2DM. This makes them more vulnerable for joint problems, non-alcoholic fatty liver disease and psychosocial consequences in upcoming years. Excess body weight makes them more likely to avoid sports or exercise due to diminished confidence during PA. If the high proportion of overweight continues throughout adolescents, the proportion of overweight young adults will remain high in Austria up to 2030, with all entailed consequences.

4.1.4. Waist-to-Height Ratio

The distribution of WHtR-class at baseline is shown in Figure 18. IS1 shows the largest proportion of children within 0.4 and 0.5 WHtR, indicating a low health risk, while IS2 had the highest proportion of children above 0.5 WHtR. Around 15% of children show increased WHtR above 0.5, therefore high probability of abdominal adiposity and elevated inflammation, inflicting them for insulin resistance and diabetes in adolescence. They have increased risk of impaired glucose tolerance even if BMI is still in normal range and are more likely to develop high blood pressure, elevated blood lipids and a metabolic syndrome, coupled to early onset of arteriosclerosis. During the intervention, the distribution of WHtR remained largely unchanged (Figure 21), with only minor, non-significant WHtR changes. CS and IS1 had small increases around 3% above 0.5 WHtR, while IS2 mild reduction of ~3% (Table 21).

4.2. Associations of school affiliation with endurance, BMI, WHtR

Data of our study suggest that there are big differences in the overall health status of primary school children, depending on school affiliation and its coupled socioeconomic background. Endurance, rates of obesity and increased WHtR differed substantially between IS1, IS2 and CS.

This underscores the need for nutritional counselling for classes with high obesity rates, as well as involvement of the entire families. Integration of repetitive dietary advice into school lessons, including printed materials, with education on topics like the Mediterranean diet and glycaemic index are highly recommended. Childhood overweight

is often correlated with the mother's education level, as mothers usually handle food purchasing and preparation. Family-based interventions are crucial as habits and cultural influences strongly affect nutrition and resulting health outcomes. Having specialized sports teachers in primary schools could lead to a quality improvement of physical education lessons. Overcoming barriers like bad weather and offering targeted training to improve strength, endurance, coordination, speed and agility, including high-intensity workouts, would greatly benefit the children. Targeted encouragement by sports teachers, which are sensibilized for additional support-needs of overweight children could minimize risk of restraint or withdrawal during physical education. They could also help setting realistic and achievable goals for fitness improvements, as well monitor them in exchange with school doctors. Organizing discovery days where children can try new sports in cooperation with local sports clubs could spark enthusiasm for physical activity in their free time. This could lead to inspiration and provide role models for children, especially those from families where sport does not play an important role at home. Promoting healthy sleep habits through school initiatives, encouraging families to keep phones outside bedrooms could help improve the educational performance and physical health of children. Educating children and parents about the addictive potential of social media, the importance of reducing screen time, and implementing mutual strategies for improvement would be further possibilities.

4.3. Health status as societal indicator

The rise in prosperity in recent decades has led to the situation that remaining chronic diseases in industrialized countries being strongly influenced by societal factors (98). This includes main determinants of health like prosperity, income, living and working conditions. The proportion of healthy individuals is a reflection of a society's goods, countries with highest average income show the best state of health (99). Risk factors like existential fears, lack of social support, depression and worry are unevenly distributed throughout populations, resulting in differences in chronic illness and life expectancy (100,101). Families who struggle to make ends meet regularly are less likely to think of long-term consequences and are more prone to addictions like tobacco and alcohol. This can increase the possibility of adverse childhood experience like emotional neglect or

physical violence. Changes in parents work structure and the working environment have a greater positive influence on familial health status and children's prosperity than specific approaches to recommend changing behaviour. The frequently made accusation that the poor cause their own illnesses is weakened by studies that show health status improves when people rise in social hierarchy, adjusting to new group norms. Behaviour always takes place in a social context, even though it initially appears to be controlled solely by the individual, acting on one's own initiative. Changing health behaviours, closing health gaps without simultaneously changing societal conditions will remain a difficult undertaking. This underscores the WHO - Ottawa charter of health promotion already published in 1986 (102), and leaves us in search of effective, evidence-based policy-making (103). Around 340.000 Austrian children and adolescents in 2024 were at risk of poverty or exclusion, corresponding to an risk of 21 percent (104). Austria provides approximately 12% of GDP per capita in child-specific cash transfers, this is the highest among all EU 27 countries (105). The transfers family allowance, child tax credit, family bonus and childcare allowance greatly contribute lowering risk of childhood poverty, especially for vulnerable groups like single parents and children under 6 years of age. For children socioeconomic status plays a key role, in higher-affluence families, especially boys, are more likely to engage in vigorous PA, and it generally declines with age especially girls, showing drops from 43% at age 11 to 28% at age 15 (106).

4.4. Prioritizing Health - From Treatment to Prevention

Prevention remains the most effective healthcare strategy, not just in aspects of cost reduction, but also in avoiding individual suffering caused by disease and subsequent complications. At the same time results are not immediate but postponed and often seem intangible. Currently resource allocation is focused on short-term and tends to be reactive, prioritizes treatment with instant results, instead of long-term proactive measures (101). Childhood obesity requires a more long-term, multisectoral prevention, something current medical systems aren't set up to cope with efficiently. This could also help mediate effects of ex-ante and ex-post moral hazards. Additional rise in expenditures may cause future problems in financing, favoured by costly innovations and demographics of an aging society. Early detection and targeted interventions for high-risk groups, families facing

precarious life circumstances are essential but underdeveloped. Family doctor appointments often just lasting 8–9 minutes makes it almost impossible to identify psychosocial problems, let alone solve them. Further, initiating positive incentives for protective behaviour should be considered. Planned health checks, outcome oriented, integrated in digital data bases with linkage to benefits could be a future way for more sustainable health care. Lack of policy making is not immediately noticeable but unethical, with negative consequences arising later. For example, trying to limit import and national production of sugar-sweetened beverages, heavily tax sugar-sweetened beverages or restricting spaces for fast food restaurants could help making the healthier choice easier. Fundamental principles of a free society must not be violated under any circumstances, but restrictions or taxation should be introduced where financial interests significantly exceed those of the common good and public health. There remains a large political responsibility to implement effective measures to address the uneven distribution of health affecting resources - income, access to education, social relationships, autonomy in the workplace, social status - across socioeconomic groups. Early action, searching for creative solutions and a decisive willingness to change status quo are necessary in order to achieve the ambitious goals of the European Guarantee for Children in Austria (107).

4.5. Strength and limitations

Our study provides a broad overview of the current situation regarding the prevalence of hypertension, overweight and obesity, increased waist-to-height ratio as well as the endurance performance of elementary school children in Austria. We were also able to show that there are significant differences in the health and performance of children from the same city, with need to investigate influential underlying factors in more detail. New ground was broken in raising awareness among teachers about current health challenges already occurring in early childhood and leaves us in search of practical and feasible movement-based learning. The success of further expanding interventions, adaptation of curricula and teaching methods will depend largely on offering evidence-based, sports science-based exercises for children. Nonetheless, the intervention was successful regarding improvement of endurance over the study period. It was also shown that only two of the 41 contracted schools agreed to participate in this sports intervention, which

illustrates that, at present time, decision-makers were not sufficiently aware of the existing problem or that other challenges in children's education were being given priority. Even within the intervention schools, there was considerable resistance from some parents, who were concerned about stigmatization of overweight children, even though these children were the ones who stood to benefit most from the intervention.

Concerning BP-measurements, multiple measurements under standardized environment were taken by a fully automatic, oscillometric device, providing independence of examiners. The anticipated ease and device acceptance by young children was high but did not prevent an occurrence of some form of “white-coat hypertension” at baseline assessment. Children measured in their first year were often nervous and unfamiliar with the experience of procedure, which could have been prevented beforehand by educating and familiarizing children with the BP measurement, as a result improve the accuracy of initial BP readings. Another option would have been to apply gold standard of manual blood pressure measurements and auscultation, though trained personnel would be required and would include potential risk for examiner variability. Gathering more blood pressure data on multiple days at all measurement points would be an improvement to detect even small changes in blood pressure with greater validity. Examining resting HR and HR variability with a validated method would provide additional physiological data and information to children's endurance capability. During Andersen running test, one of the most important points is to optimize standardized conditions. Factors such as the indoor hall’s climate, the number of participating children (risk of collisions), and the children's recovery status on the day of testing should be considered. The findings of the study show the results of 485 pupils and the limited amount of data collected at the three measurement points. Future studies could increase the number of pupils including different regions and more frequent measurements, extend the duration of the intervention, and re-evaluate children as they progress through their education in adolescents to obtain an even more comprehensive picture.

4.6. Compliance with ethical standards

All procedures in this study complied with the ethical standards approved by the Research Ethics Committee of the Medical University of Graz, Austria (33-488 ex 20/21). The study was registered on ClinicalTrials.gov (NCT04956003). Children were voluntarily enrolled in the HAPHC project, with written informed consent obtained from their legal guardians as a prerequisite for participation. Participation was entirely voluntary, and both refusal to take part in specific measurements and withdrawal from the study were permitted at any time.

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Appendix

Figure 22 - Happy Children Testing Team

Figure 23 - Andersen Running Test – Assessment Sheet

ANDERSEN-LAUFTEST | CODE:**HC**_ _ - _ _ _

NAME DER SCHULE: | KLASSE: _____

DATUM:_____2021 | Gültig: Ungültig: Unsicher: (Tick)

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80

Kommentar: (Schuhe, Laufmuster, Testunterbrechung, Krankheit, etc.)	**Meter letzte Runde:**

Table 22 - Blood pressure reference values male by age (6-12) and height percentile

Blood Pressure Reference - Male															
Age	Bp Percentile	SBP (mmHg) Height							DBP (mmHg) Height						
		5%	10%	25%	50%	75%	90%	95%	5%	10%	25%	50%	75%	90%	95%
6	Height (cm)	110,3	112,2	115,3	118,9	122,4	125,6	127,5	110,3	112,2	115,3	118,9	122,4	125,6	127,5
	50th	93	93	94	95	96	97	98	54	54	55	56	57	57	58
	90th	105	105	106	107	109	110	110	66	66	67	68	68	69	69
	95th	108	109	110	111	112	113	114	69	70	70	71	72	72	73
	95th+12mmHg	120	121	122	123	124	125	126	81	82	82	83	84	84	85
7	Height (cm)	116,1	118	121,4	125,1	128,9	132,4	134,5	116,1	118	121,4	125,1	128,9	132,4	134,5
	50th	94	94	95	97	98	98	99	56	56	57	58	58	59	59
	90th	106	107	108	109	110	111	111	68	68	69	70	70	71	71
	95th	110	110	111	112	114	115	116	71	71	72	73	73	74	74
	95th+12mmHg	122	122	123	124	126	127	128	83	83	84	85	85	86	86
8	Height (cm)	121,4	123,5	127	131	135,1	138,8	141	121,4	123,5	127	131	135,1	138,8	141
	50th	95	96	97	98	99	99	100	57	57	58	59	59	60	60
	90th	107	108	109	110	111	112	112	69	70	70	71	72	72	73
	95th	111	112	112	114	115	116	117	72	73	73	74	75	75	75
	95th+12mmHg	123	124	124	126	127	128	129	84	85	85	86	87	87	87
9	Height (cm)	126	128,3	132,1	136,3	140,7	144,7	147,1	126	128,3	132,1	136,3	140,7	144,7	147,1
	50th	96	97	98	99	100	101	101	57	58	59	60	61	62	62
	90th	107	108	109	110	112	113	114	70	71	72	73	74	74	74
	95th	112	112	113	115	116	118	119	74	74	75	76	76	77	77
	95th+12mmHg	124	124	125	127	128	130	131	86	86	87	88	88	89	89
10	Height (cm)	130,2	132,7	136,7	141,3	145,9	150,1	152,7	130,2	132,7	136,7	141,3	145,9	150,1	152,7
	50th	97	98	99	100	101	102	103	59	60	61	62	63	63	64
	90th	108	109	111	112	113	115	116	72	73	74	74	75	75	76
	95th	112	113	114	116	118	120	121	76	76	77	78	78	78	78
	95th+12mmHg	124	125	126	128	130	132	133	88	88	89	89	90	90	90
11	Height (cm)	134,7	137,3	141,5	146,4	151,3	155,8	158,6	134,7	137,3	141,5	146,4	151,3	155,8	158,6
	50th	99	99	101	102	103	104	106	61	61	62	63	63	63	63
	90th	110	111	112	114	116	117	118	74	74	75	75	75	76	76
	95th	114	114	116	118	120	123	124	77	78	78	78	78	78	78
	95th+12mmHg	126	126	128	130	132	135	136	89	90	90	90	90	90	90
12	Height (cm)	140,3	143	147,5	152,7	157,9	162,6	165,5	140,3	143	147,5	152,7	157,9	162,6	165,5
	50th	101	101	102	104	106	108	109	61	62	62	62	62	63	63
	90th	113	114	115	117	119	121	122	75	75	75	75	75	76	76
	95th	116	117	118	121	124	126	128	78	78	78	78	78	79	79
	95th+12mmHg	128	129	130	133	136	138	140	90	90	90	90	90	91	91

BP = blood pressure; SBP = systolic blood pressure; DBP = diastolic blood pressure; height in cm

Source: Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents (American Academy oF Pediatrics)

Table 23 - Blood pressure reference values female by age (6-12) and height percentile

Blood Pressure Reference - Female															
Age	Bp Percentile	SBP (mmHg) Height							DBP (mmHg) Height						
		5%	10%	25%	50%	75%	90%	95%	5%	10%	25%	50%	75%	90%	95%
6	Height (cm)	110	111,8	114,9	118,4	122,1	125,6	127,7	110	111,8	114,9	118,4	122,1	125,6	127,7
	50th	92	92	93	94	96	97	97	54	54	55	56	57	58	59
	90th	105	106	107	108	109	110	111	67	67	68	69	70	71	71
	95th	109	109	110	111	112	113	114	70	71	72	72	73	74	74
	95th+12mmHg	121	121	122	123	124	125	126	82	83	84	84	85	86	86
7	Height (cm)	115,9	117,8	121,1	124,9	128,8	132,5	134,7	115,9	117,8	121,1	124,9	128,8	132,5	134,7
	50th	92	93	94	95	97	98	99	55	55	56	57	58	59	60
	90th	106	106	107	109	110	111	112	68	68	69	70	71	72	72
	95th	109	110	111	112	113	114	115	72	72	73	73	74	74	75
	95th+12mmHg	121	122	123	124	125	126	127	84	84	85	85	86	86	87
8	Height (cm)	121	123	126,5	130,6	134,7	138,5	140,9	121	123	126,5	130,6	134,7	138,5	140,9
	50th	93	94	95	97	98	99	100	56	56	57	59	60	61	61
	90th	107	107	108	110	111	112	113	69	70	71	72	72	73	73
	95th	110	111	112	113	115	116	117	72	73	74	74	75	75	75
	95th+12mmHg	122	123	124	125	127	128	129	84	85	86	86	87	87	87
9	Height (cm)	125,3	127,6	131,3	135,6	140,1	144,1	146,6	125,3	127,6	131,3	135,6	140,1	144,1	146,6
	50th	95	95	97	98	99	100	101	57	58	59	60	60	61	61
	90th	108	108	109	111	112	113	114	71	71	72	73	73	73	73
	95th	112	112	113	114	116	117	118	74	74	75	75	75	75	75
	95th+12mmHg	124	124	125	126	128	129	130	86	86	87	87	87	87	87
10	Height (cm)	129,7	132,2	136,3	141	145,8	150,2	152,8	129,7	132,2	136,3	141	145,8	150,2	152,8
	50th	96	97	98	99	101	102	103	58	59	59	60	61	61	62
	90th	109	110	111	112	113	115	116	72	73	73	73	73	73	73
	95th	113	114	114	116	117	119	120	75	75	76	76	76	76	76
	95th+12mmHg	125	126	126	128	129	131	132	87	87	88	88	88	88	88
11	Height (cm)	135,6	138,3	142,8	147,8	152,8	157,3	160	135,6	138,3	142,8	147,8	152,8	157,3	160
	50th	98	99	101	102	104	105	106	60	60	60	61	62	63	64
	90th	111	112	113	114	116	118	120	74	74	74	74	74	75	75
	95th	115	116	117	118	120	123	124	76	77	77	77	77	77	77
	95th+12mmHg	127	128	129	130	132	135	138	88	89	89	89	89	89	89
12	Height (cm)	142,8	145,5	149,9	154,8	159,6	163,8	166,4	142,8	145,5	149,9	154,8	159,6	163,8	166,4
	50th	102	102	104	105	107	108	108	61	61	61	62	64	65	65
	90th	114	115	116	118	120	122	122	75	75	75	75	76	76	76
	95th	118	119	120	122	124	125	126	78	78	78	78	79	79	79
	95th+12mmHg	130	131	132	134	136	137	138	90	90	90	90	91	91	91

BP = blood pressure; SBP = systolic blood pressure; DBP = diastolic blood pressure; height in cm

Source: Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents (American Academy oF Pediatrics)

Table 24 - BMI reference values male

				BMI Reference												
Male	Age Days	Age Months	Age Years	L	M	S	P3	P5	P10	P25	P50	P75	P85	P90	P95	P97
1	2175	71,5	6,0	-3,18	15,38	0,08	13,56	13,74	14,04	14,61	15,38	16,35	16,99	17,49	18,36	19,04
1	2205	72,5	6,0	-3,21	15,38	0,08	13,55	13,74	14,04	14,61	15,38	16,36	17,01	17,52	18,41	19,11
1	2236	73,5	6,1	-3,24	15,39	0,08	13,55	13,73	14,03	14,61	15,39	16,38	17,04	17,56	18,47	19,18
1	2266	74,5	6,2	-3,26	15,39	0,08	13,54	13,73	14,03	14,61	15,39	16,40	17,07	17,59	18,52	19,25
1	2296	75,5	6,3	-3,28	15,40	0,09	13,54	13,72	14,03	14,61	15,40	16,41	17,09	17,63	18,58	19,33
1	2327	76,5	6,4	-3,29	15,41	0,09	13,54	13,72	14,03	14,61	15,41	16,43	17,12	17,67	18,64	19,41
1	2357	77,5	6,5	-3,31	15,42	0,09	13,53	13,72	14,03	14,62	15,42	16,45	17,15	17,71	18,70	19,48
1	2388	78,5	6,5	-3,31	15,43	0,09	13,53	13,72	14,03	14,62	15,43	16,47	17,18	17,75	18,76	19,56
1	2418	79,5	6,6	-3,32	15,44	0,09	13,53	13,72	14,03	14,62	15,44	16,50	17,22	17,79	18,82	19,65
1	2449	80,5	6,7	-3,33	15,45	0,09	13,53	13,72	14,03	14,63	15,45	16,52	17,25	17,83	18,88	19,73
1	2479	81,5	6,8	-3,33	15,47	0,09	13,53	13,72	14,03	14,64	15,47	16,55	17,29	17,88	18,95	19,82
1	2509	82,5	6,9	-3,33	15,48	0,09	13,53	13,72	14,03	14,64	15,48	16,57	17,32	17,93	19,01	19,90
1	2540	83,5	7,0	-3,33	15,50	0,09	13,53	13,72	14,04	14,65	15,50	16,60	17,36	17,97	19,08	19,99
1	2570	84,5	7,0	-3,32	15,51	0,09	13,53	13,72	14,04	14,66	15,51	16,63	17,40	18,02	19,15	20,08
1	2601	85,5	7,1	-3,32	15,53	0,09	13,53	13,72	14,05	14,67	15,53	16,66	17,44	18,07	19,22	20,17
1	2631	86,5	7,2	-3,31	15,55	0,09	13,53	13,73	14,05	14,68	15,55	16,69	17,48	18,12	19,29	20,26
1	2661	87,5	7,3	-3,30	15,57	0,09	13,54	13,73	14,06	14,69	15,57	16,72	17,53	18,18	19,37	20,36
1	2692	88,5	7,4	-3,29	15,59	0,10	13,54	13,74	14,07	14,70	15,59	16,76	17,57	18,23	19,44	20,45
1	2722	89,5	7,5	-3,28	15,61	0,10	13,54	13,74	14,07	14,72	15,61	16,79	17,61	18,28	19,52	20,55
1	2753	90,5	7,5	-3,27	15,63	0,10	13,55	13,75	14,08	14,73	15,63	16,83	17,66	18,34	19,59	20,64
1	2783	91,5	7,6	-3,26	15,65	0,10	13,55	13,75	14,09	14,75	15,65	16,86	17,71	18,40	19,67	20,74
1	2814	92,5	7,7	-3,24	15,68	0,10	13,56	13,76	14,10	14,76	15,68	16,90	17,76	18,45	19,75	20,84
1	2844	93,5	7,8	-3,23	15,70	0,10	13,56	13,77	14,11	14,78	15,70	16,94	17,80	18,51	19,83	20,94
1	2874	94,5	7,9	-3,21	15,73	0,10	13,57	13,78	14,12	14,79	15,73	16,98	17,85	18,57	19,91	21,03
1	2905	95,5	8,0	-3,20	15,76	0,10	13,58	13,79	14,13	14,81	15,76	17,02	17,90	18,63	19,99	21,13
1	2935	96,5	8,0	-3,18	15,78	0,10	13,59	13,80	14,15	14,83	15,78	17,06	17,96	18,69	20,07	21,24
1	2966	97,5	8,1	-3,17	15,81	0,10	13,59	13,81	14,16	14,85	15,81	17,10	18,01	18,75	20,15	21,34
1	2996	98,5	8,2	-3,15	15,84	0,10	13,60	13,82	14,17	14,87	15,84	17,14	18,06	18,82	20,23	21,44
1	3026	99,5	8,3	-3,13	15,87	0,10	13,61	13,83	14,19	14,89	15,87	17,19	18,12	18,88	20,32	21,54
1	3057	100,5	8,4	-3,11	15,90	0,11	13,62	13,84	14,20	14,91	15,90	17,23	18,17	18,94	20,40	21,64
1	3087	101,5	8,5	-3,10	15,93	0,11	13,64	13,85	14,22	14,93	15,93	17,27	18,23	19,01	20,48	21,75
1	3118	102,5	8,5	-3,08	15,96	0,11	13,65	13,87	14,24	14,95	15,96	17,32	18,28	19,08	20,57	21,85
1	3148	103,5	8,6	-3,06	15,99	0,11	13,66	13,88	14,25	14,98	15,99	17,37	18,34	19,14	20,65	21,95
1	3179	104,5	8,7	-3,04	16,03	0,11	13,67	13,90	14,27	15,00	16,03	17,41	18,40	19,21	20,74	22,06
1	3209	105,5	8,8	-3,03	16,06	0,11	13,69	13,91	14,29	15,03	16,06	17,46	18,45	19,28	20,83	22,16
1	3239	106,5	8,9	-3,01	16,10	0,11	13,70	13,93	14,31	15,05	16,10	17,51	18,51	19,34	20,91	22,27
1	3270	107,5	9,0	-2,99	16,13	0,11	13,72	13,94	14,33	15,08	16,13	17,56	18,57	19,41	21,00	22,37
1	3300	108,5	9,0	-2,97	16,17	0,11	13,73	13,96	14,35	15,10	16,17	17,61	18,63	19,48	21,09	22,48
1	3331	109,5	9,1	-2,95	16,20	0,11	13,75	13,98	14,37	15,13	16,20	17,66	18,69	19,55	21,18	22,58
1	3361	110,5	9,2	-2,94	16,24	0,11	13,76	14,00	14,39	15,16	16,24	17,71	18,75	19,62	21,26	22,69
1	3391	111,5	9,3	-2,92	16,28	0,11	13,78	14,02	14,41	15,19	16,28	17,76	18,82	19,69	21,35	22,79
1	3422	112,5	9,4	-2,90	16,32	0,11	13,80	14,04	14,44	15,22	16,32	17,81	18,88	19,76	21,44	22,90
1	3452	113,5	9,5	-2,88	16,36	0,12	13,82	14,06	14,46	15,25	16,36	17,86	18,94	19,83	21,53	23,00
1	3483	114,5	9,5	-2,87	16,40	0,12	13,84	14,08	14,48	15,28	16,40	17,92	19,00	19,91	21,62	23,10
1	3513	115,5	9,6	-2,85	16,44	0,12	13,86	14,10	14,51	15,31	16,44	17,97	19,07	19,98	21,71	23,21
1	3544	116,5	9,7	-2,83	16,48	0,12	13,88	14,12	14,53	15,34	16,48	18,02	19,13	20,05	21,80	23,31
1	3574	117,5	9,8	-2,81	16,52	0,12	13,90	14,15	14,56	15,37	16,52	18,08	19,20	20,12	21,89	23,42
1	3604	118,5	9,9	-2,80	16,56	0,12	13,92	14,17	14,59	15,41	16,56	18,13	19,26	20,20	21,98	23,52
1	3635	119,5	10,0	-2,78	16,60	0,12	13,94	14,19	14,61	15,44	16,60	18,19	19,32	20,27	22,06	23,62
1	3665	120,5	10,0	-2,77	16,65	0,12	13,97	14,22	14,64	15,47	16,65	18,25	19,39	20,34	22,15	23,73
1	3696	121,5	10,1	-2,75	16,69	0,12	13,99	14,24	14,67	15,51	16,69	18,30	19,46	20,42	22,24	23,83
1	3726	122,5	10,2	-2,73	16,73	0,12	14,01	14,27	14,70	15,54	16,73	18,36	19,52	20,49	22,33	23,93
1	3756	123,5	10,3	-2,72	16,78	0,12	14,04	14,30	14,73	15,58	16,78	18,42	19,59	20,56	22,42	24,03
1	3787	124,5	10,4	-2,70	16,82	0,12	14,06	14,32	14,76	15,61	16,82	18,47	19,66	20,64	22,51	24,13
1	3817	125,5	10,5	-2,69	16,87	0,12	14,09	14,35	14,79	15,65	16,87	18,53	19,72	20,71	22,60	24,24
1	3848	126,5	10,5	-2,67	16,92	0,12	14,12	14,38	14,82	15,69	16,92	18,59	19,79	20,79	22,69	24,34
1	3878	127,5	10,6	-2,66	16,96	0,12	14,14	14,41	14,85	15,73	16,96	18,65	19,86	20,86	22,78	24,44
1	3909	128,5	10,7	-2,65	17,01	0,12	14,17	14,44	14,89	15,76	17,01	18,71	19,92	20,94	22,86	24,54
1	3939	129,5	10,8	-2,63	17,06	0,13	14,20	14,47	14,92	15,80	17,06	18,77	19,99	21,01	22,95	24,63
1	3969	130,5	10,9	-2,62	17,10	0,13	14,23	14,50	14,95	15,84	17,10	18,83	20,06	21,09	23,04	24,73
1	4000	131,5	11,0	-2,60	17,15	0,13	14,26	14,53	14,99	15,88	17,15	18,89	20,13	21,16	23,13	24,83
1	4030	132,5	11,0	-2,59	17,20	0,13	14,29	14,56	15,02	15,92	17,20	18,95	20,20	21,24	23,21	24,93
1	4061	133,5	11,1	-2,58	17,25	0,13	14,32	14,59	15,06	15,96	17,25	19,01	20,27	21,31	23,30	25,02
1	4091	134,5	11,2	-2,56	17,30	0,13	14,35	14,62	15,09	16,00	17,30	19,07	20,33	21,39	23,39	25,12
1	4121	135,5	11,3	-2,55	17,35	0,13	14,38	14,66	15,13	16,05	17,35	19,13	20,40	21,46	23,47	25,21
1	4152	136,5	11,4	-2,54	17,40	0,13	14,41	14,69	15,16	16,09	17,40	19,19	20,47	21,54	23,56	25,31
1	4182	137,5	11,5	-2,53	17,45	0,13	14,44	14,73	15,20	16,13	17,45	19,25	20,54	21,61	23,64	25,40
1	4213	138,5	11,5	-2,52	17,50	0,13	14,48	14,76	15,24	16,17	17,50	19,31	20,61	21,69	23,73	25,49
1	4243	139,5	11,6	-2,50	17,55	0,13	14,51	14,79	15,28	16,22	17,55	19,37	20,68	21,76	23,81	25,58
1	4274	140,5	11,7	-2,49	17,60	0,13	14,54	14,83	15,31	16,26	17,60	19,44	20,75	21,84	23,90	25,68
1	4304	141,5	11,8	-2,48	17,66	0,13	14,58	14,87	15,35	16,31	17,66	19,50	20,82	21,91	23,98	25,77
1	4334	142,5	11,9	-2,47	17,71	0,13	14,61	14,90	15,39	16,35	17,71	19,56	20,89	21,98	24,06	25,86
1	4365	143,5	12,0	-2,46	17,76	0,13	14,65	14,94	15,43	16,40	17,76	19,62	20,95	22,06	24,15	25,94
1	4395	144,5	12,0	-2,45	17,81	0,13	14,68	14,98	15,47	16,44	17,81	19,69	21,02	22,13	24,23	26,03
1	4426	145,5	12,1	-2,44	17,87	0,13	14,72	15,02	15,51	16,49	17,87	19,75	21,09	22,21	24,31	26,12
1	4456	146,5	12,2	-2,43	17,92	0,13	14,76	15,05	15,55	16,53	17,92	19,81	21,16	22,28	24,39	26,21
1	4486	147,5	12,3	-2,42	17,98	0,13	14,79	15,09	15,59	16,58	17,98	19,88	21,23	22,35	24,47	26,29
1	4517	148,5	12,4	-2,41	18,03	0,13	14,83	15,13	15,64	16,63	18,03	19,94	21,30	22,43	24,55	26,38
1	4547	149,5	12,5	-2,40	18,08	0,13	14,87	15,17	15,68	16,67	18,08	20,00	21,37	22,50	24,63	26,46
1	4578	150,5	12,5	-2,39	18,14	0,13	14,91	15,21	15,72	16,72	18,14	20,07	21,44	22,57	24,71	26,54
1	4608	151,5	12,6	-2,38	18,19	0,13	14,95	15,25	15,76	16,77	18,19	20,13	21,51	22,65	24,79	26,62
1	4639	152,5	12,7	-2,37	18,25	0,13	14,99	15,29	15,81	16,82	18,25	20,19	21,58	22,72	24,87	26,71
1	4669	153,5	12,8	-2,36	18,30	0,13	15,03	15,33	15,85	16,87	18,30	20,26	21,65	22,79	24,95	26,79
1	4699	154,5	12,9	-2,35	18,36	0,13	15,07	15,38	15,90	16,92	18,36	20,32	21,71	22,86	25,03	26,86

Source: Centers for Disease Control and Prevention, National Center for Health Statistics - www.cdc.gov/growthcharts/cdc-data-files.htm

Table 25 - BMI reference values female

				BMI Reference												
Female	Age Days	Age Months	Age Years	L	M	S	P3	P5	P10	P25	P50	P75	P85	P90	P95	P97
2	2175	71,5	6,0	-3,25	15,20	0,09	13,24	13,43	13,75	14,36	15,20	16,31	17,07	17,67	18,78	19,68
2	2205	72,5	6,0	-3,23	15,22	0,09	13,23	13,43	13,75	14,37	15,22	16,33	17,10	17,72	18,84	19,75
2	2236	73,5	6,1	-3,20	15,23	0,09	13,23	13,42	13,75	14,37	15,23	16,36	17,14	17,76	18,90	19,83
2	2266	74,5	6,2	-3,18	15,25	0,10	13,22	13,42	13,75	14,38	15,25	16,39	17,17	17,81	18,96	19,91
2	2296	75,5	6,3	-3,16	15,26	0,10	13,22	13,42	13,75	14,38	15,26	16,42	17,21	17,85	19,03	19,99
2	2327	76,5	6,4	-3,13	15,28	0,10	13,22	13,42	13,75	14,39	15,28	16,45	17,25	17,90	19,09	20,07
2	2357	77,5	6,5	-3,11	15,30	0,10	13,22	13,42	13,75	14,40	15,30	16,48	17,29	17,95	19,16	20,16
2	2388	78,5	6,5	-3,08	15,32	0,10	13,21	13,42	13,76	14,41	15,32	16,51	17,34	18,01	19,23	20,24
2	2418	79,5	6,6	-3,06	15,34	0,10	13,21	13,42	13,76	14,42	15,34	16,55	17,38	18,06	19,30	20,33
2	2449	80,5	6,7	-3,03	15,36	0,10	13,21	13,42	13,76	14,43	15,36	16,58	17,43	18,12	19,37	20,42
2	2479	81,5	6,8	-3,01	15,38	0,10	13,21	13,42	13,77	14,45	15,38	16,62	17,48	18,17	19,45	20,50
2	2509	82,5	6,9	-2,98	15,40	0,10	13,21	13,42	13,78	14,46	15,40	16,66	17,52	18,23	19,52	20,60
2	2540	83,5	7,0	-2,95	15,43	0,10	13,22	13,43	13,78	14,47	15,43	16,69	17,57	18,29	19,60	20,69
2	2570	84,5	7,0	-2,93	15,45	0,11	13,22	13,43	13,79	14,49	15,45	16,73	17,63	18,35	19,68	20,78
2	2601	85,5	7,1	-2,90	15,48	0,11	13,22	13,44	13,80	14,50	15,48	16,78	17,68	18,41	19,76	20,88
2	2631	86,5	7,2	-2,87	15,51	0,11	13,23	13,44	13,81	14,52	15,51	16,82	17,73	18,47	19,84	20,97
2	2661	87,5	7,3	-2,85	15,54	0,11	13,23	13,45	13,82	14,54	15,54	16,86	17,79	18,54	19,92	21,07
2	2692	88,5	7,4	-2,82	15,56	0,11	13,23	13,46	13,83	14,56	15,56	16,91	17,84	18,60	20,00	21,17
2	2722	89,5	7,5	-2,79	15,59	0,11	13,24	13,47	13,84	14,58	15,59	16,95	17,90	18,67	20,08	21,26
2	2753	90,5	7,5	-2,77	15,63	0,11	13,25	13,47	13,86	14,60	15,63	17,00	17,95	18,73	20,17	21,36
2	2783	91,5	7,6	-2,74	15,66	0,11	13,25	13,48	13,87	14,62	15,66	17,04	18,01	18,80	20,25	21,47
2	2814	92,5	7,7	-2,72	15,69	0,11	13,26	13,49	13,88	14,64	15,69	17,09	18,07	18,87	20,34	21,57
2	2844	93,5	7,8	-2,69	15,72	0,11	13,27	13,50	13,90	14,66	15,72	17,14	18,13	18,94	20,43	21,67
2	2874	94,5	7,9	-2,67	15,76	0,12	13,28	13,52	13,91	14,68	15,76	17,19	18,19	19,01	20,52	21,77
2	2905	95,5	8,0	-2,64	15,79	0,12	13,29	13,53	13,93	14,71	15,79	17,24	18,25	19,08	20,61	21,88
2	2935	96,5	8,0	-2,62	15,83	0,12	13,30	13,54	13,94	14,73	15,83	17,29	18,32	19,15	20,70	21,98
2	2966	97,5	8,1	-2,59	15,86	0,12	13,31	13,55	13,96	14,76	15,86	17,34	18,38	19,23	20,79	22,09
2	2996	98,5	8,2	-2,57	15,90	0,12	13,32	13,57	13,98	14,78	15,90	17,40	18,44	19,30	20,88	22,19
2	3026	99,5	8,3	-2,55	15,94	0,12	13,34	13,58	14,00	14,81	15,94	17,45	18,51	19,37	20,97	22,30
2	3057	100,5	8,4	-2,52	15,98	0,12	13,35	13,60	14,02	14,83	15,98	17,50	18,57	19,45	21,06	22,41
2	3087	101,5	8,5	-2,50	16,02	0,12	13,36	13,61	14,04	14,86	16,02	17,56	18,64	19,52	21,15	22,51
2	3118	102,5	8,5	-2,48	16,06	0,12	13,38	13,63	14,06	14,89	16,06	17,61	18,71	19,60	21,25	22,62
2	3148	103,5	8,6	-2,46	16,10	0,12	13,39	13,65	14,08	14,92	16,10	17,67	18,77	19,68	21,34	22,73
2	3179	104,5	8,7	-2,44	16,14	0,12	13,41	13,67	14,10	14,95	16,14	17,73	18,84	19,75	21,44	22,84
2	3209	105,5	8,8	-2,42	16,18	0,13	13,42	13,68	14,12	14,98	16,18	17,78	18,91	19,83	21,53	22,95
2	3239	106,5	8,9	-2,40	16,22	0,13	13,44	13,70	14,15	15,01	16,22	17,84	18,98	19,91	21,63	23,06
2	3270	107,5	9,0	-2,38	16,26	0,13	13,46	13,72	14,17	15,04	16,26	17,90	19,05	19,99	21,72	23,17
2	3300	108,5	9,0	-2,36	16,31	0,13	13,48	13,74	14,19	15,07	16,31	17,96	19,12	20,07	21,82	23,28
2	3331	109,5	9,1	-2,34	16,35	0,13	13,49	13,77	14,22	15,11	16,35	18,02	19,19	20,15	21,91	23,39
2	3361	110,5	9,2	-2,32	16,39	0,13	13,51	13,79	14,25	15,14	16,39	18,08	19,26	20,23	22,01	23,50
2	3391	111,5	9,3	-2,31	16,44	0,13	13,53	13,81	14,27	15,17	16,44	18,14	19,33	20,31	22,11	23,61
2	3422	112,5	9,4	-2,29	16,48	0,13	13,55	13,83	14,30	15,21	16,48	18,20	19,40	20,39	22,20	23,72
2	3452	113,5	9,5	-2,27	16,53	0,13	13,58	13,86	14,33	15,24	16,53	18,26	19,47	20,47	22,30	23,83
2	3483	114,5	9,5	-2,26	16,58	0,13	13,60	13,88	14,35	15,28	16,58	18,32	19,55	20,55	22,40	23,94
2	3513	115,5	9,6	-2,24	16,62	0,13	13,62	13,90	14,38	15,31	16,62	18,38	19,62	20,63	22,50	24,05
2	3544	116,5	9,7	-2,23	16,67	0,13	13,64	13,93	14,41	15,35	16,67	18,44	19,69	20,71	22,59	24,16
2	3574	117,5	9,8	-2,21	16,72	0,13	13,67	13,95	14,44	15,39	16,72	18,51	19,76	20,79	22,69	24,27
2	3604	118,5	9,9	-2,20	16,77	0,14	13,69	13,98	14,47	15,42	16,77	18,57	19,84	20,87	22,79	24,38
2	3635	119,5	10,0	-2,18	16,81	0,14	13,72	14,01	14,50	15,46	16,81	18,63	19,91	20,95	22,89	24,49
2	3665	120,5	10,0	-2,17	16,86	0,14	13,74	14,04	14,53	15,50	16,86	18,70	19,98	21,04	22,98	24,60
2	3696	121,5	10,1	-2,16	16,91	0,14	13,77	14,06	14,56	15,54	16,91	18,76	20,06	21,12	23,08	24,71
2	3726	122,5	10,2	-2,15	16,96	0,14	13,79	14,09	14,59	15,58	16,96	18,82	20,13	21,20	23,18	24,82
2	3756	123,5	10,3	-2,13	17,01	0,14	13,82	14,12	14,63	15,62	17,01	18,89	20,20	21,28	23,27	24,93
2	3787	124,5	10,4	-2,12	17,06	0,14	13,85	14,15	14,66	15,66	17,06	18,95	20,28	21,36	23,37	25,04
2	3817	125,5	10,5	-2,11	17,11	0,14	13,88	14,18	14,69	15,70	17,11	19,01	20,35	21,45	23,47	25,15
2	3848	126,5	10,5	-2,10	17,16	0,14	13,90	14,21	14,73	15,74	17,16	19,08	20,43	21,53	23,57	25,26
2	3878	127,5	10,6	-2,09	17,21	0,14	13,93	14,24	14,76	15,78	17,21	19,14	20,50	21,61	23,66	25,37
2	3909	128,5	10,7	-2,08	17,26	0,14	13,96	14,27	14,80	15,82	17,26	19,21	20,57	21,69	23,76	25,48
2	3939	129,5	10,8	-2,07	17,31	0,14	13,99	14,30	14,83	15,86	17,31	19,27	20,65	21,77	23,85	25,59
2	3969	130,5	10,9	-2,06	17,37	0,14	14,02	14,34	14,87	15,90	17,37	19,34	20,72	21,86	23,95	25,69
2	4000	131,5	11,0	-2,05	17,42	0,14	14,05	14,37	14,90	15,95	17,42	19,40	20,80	21,94	24,05	25,80
2	4030	132,5	11,0	-2,05	17,47	0,14	14,08	14,40	14,94	15,99	17,47	19,46	20,87	22,02	24,14	25,91
2	4061	133,5	11,1	-2,04	17,52	0,14	14,12	14,44	14,98	16,03	17,52	19,53	20,94	22,10	24,24	26,02
2	4091	134,5	11,2	-2,03	17,57	0,14	14,15	14,47	15,01	16,08	17,57	19,59	21,02	22,18	24,33	26,12
2	4121	135,5	11,3	-2,02	17,63	0,15	14,18	14,51	15,05	16,12	17,63	19,66	21,09	22,26	24,43	26,23
2	4152	136,5	11,4	-2,02	17,68	0,15	14,21	14,54	15,09	16,16	17,68	19,72	21,16	22,34	24,52	26,33
2	4182	137,5	11,5	-2,01	17,73	0,15	14,25	14,58	15,13	16,21	17,73	19,79	21,24	22,42	24,61	26,44
2	4213	138,5	11,5	-2,00	17,78	0,15	14,28	14,61	15,17	16,25	17,78	19,85	21,31	22,50	24,71	26,54
2	4243	139,5	11,6	-2,00	17,84	0,15	14,32	14,65	15,20	16,30	17,84	19,92	21,38	22,58	24,80	26,65
2	4274	140,5	11,7	-1,99	17,89	0,15	14,35	14,68	15,24	16,34	17,89	19,98	21,45	22,66	24,89	26,75
2	4304	141,5	11,8	-1,99	17,94	0,15	14,39	14,72	15,28	16,39	17,94	20,04	21,53	22,74	24,98	26,85
2	4334	142,5	11,9	-1,98	18,00	0,15	14,42	14,76	15,32	16,43	18,00	20,11	21,60	22,82	25,07	26,95
2	4365	143,5	12,0	-1,98	18,05	0,15	14,46	14,79	15,36	16,48	18,05	20,17	21,67	22,90	25,17	27,05
2	4395	144,5	12,0	-1,98	18,10	0,15	14,49	14,83	15,40	16,52	18,10	20,24	21,74	22,97	25,26	27,16
2	4426	145,5	12,1	-1,97	18,15	0,15	14,53	14,87	15,44	16,57	18,15	20,30	21,81	23,05	25,35	27,26
2	4456	146,5	12,2	-1,97	18,21	0,15	14,57	14,91	15,48	16,61	18,21	20,36	21,88	23,13	25,43	27,36
2	4486	147,5	12,3	-1,97	18,26	0,15	14,61	14,95	15,53	16,66	18,26	20,43	21,96	23,21	25,52	27,46
2	4517	148,5	12,4	-1,96	18,31	0,15	14,64	14,99	15,57	16,71	18,31	20,49	22,03	23,28	25,61	27,55
2	4547	149,5	12,5	-1,96	18,37	0,15	14,68	15,03	15,61	16,75	18,37	20,55	22,10	23,36	25,70	27,65
2	4578	150,5	12,5	-1,96	18,42	0,15	14,72	15,07	15,65	16,80	18,42	20,61	22,17	23,43	25,79	27,75
2	4608	151,5	12,6	-1,96	18,47	0,15	14,76	15,11	15,69	16,84	18,47	20,68	22,23	23,51	25,87	27,85
2	4639	152,5	12,7	-1,96	18,53	0,15	14,80	15,15	15,73	16,89	18,53	20,74	22,30	23,58	25,96	27,94
2	4669	153,5	12,8	-1,96	18,58	0,15	14,83	15,19	15,78	16,94	18,58	20,80	22,37	23,66	26,05	28,04
2	4699	154,5	12,9	-1,96	18,63	0,15	14,87	15,23	15,82	16,98	18,63	20,86	22,44	23,73	26,13	28,13

Source: Centers for Disease Control and Prevention, National Center for Health Statistics - www.cdc.gov/growthcharts/cdc-data-files.htm