Short- and long-term effects of a multi-component physical activity intervention in primary school

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auf Antrag von

Fakultätsverantwortlicher	|	Prof. Dr. med. Arno Schmidt-Trucksäss
Dissertationsleiterin	|	PD Dr. med. Susi Kriemler
Koreferentin	|	PD Dr. med. Jardena Puder
Externer Experte	|	Prof. Dr. Willem van Mechelen

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Dekan

Prof. Dr. med. Christoph Beglinger

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Summary
Zusammenfassung

SUMMARY

There is compelling evidence that physical activity has numerous health benefits during childhood and adolescence. Insufficient levels of physical activity on the other hand can consequently affect cardiovascular and bone health, which may result in severe chronic diseases later in life. Cardiovascular disease and osteoporosis are two of the major chronic diseases affecting a large proportion of the adult population. Both diseases have their origins in childhood and it has been shown that for both, physical activity plays an important role in their prevention. The number of children not being sufficiently active has reached an alarming level and threatens to impose major health burdens worldwide. Thus, developing effective strategies to enhance children's physical activity levels is of paramount interest for public health. School provides an optimal setting for physical activity promotion, since all children spend a large portion of their time there. This dissertation discusses a school-based randomized controlled trial aimed at increasing children's physical activity levels and consequently their cardiovascular and bone health.

The „Kinder- und Jugendsportstudie" (KISS) is a school-based physical activity intervention lasting one school year. Of all primary school classes in the cantons of Aargau and Baselland comprising about 10% of the Swiss population, 28 first and fifth grade classes were randomly selected and allocated into an intervention (16 classes; n=297 children) and a control (12 classes, n=205 children) group. The mandatory and stringent multi-component intervention program consisted of daily physical education lessons (of which two lessons were taught by a physical education teacher and three lessons were taught by the primary school teacher), daily short activity breaks during academic lessons, and physical activity homework. Children in the control group had the compulsory three physical educations per week.

The aim of this dissertation was, to assess the effectiveness of KISS on cardiovascular risk and bone health and to explore whether the program was sufficiently effective in order to maintain health benefits over the following three years. In addition, this dissertation will provide a systematic update of existing school-based intervention studies aiming at increasing children's physical activity and a quantification of physical education-related physical activity.

There is strong evidence that school provides a promising setting for physical activity promotion. All school-based intervention studies done in recent years showed positive effects in at least one domain of physical activity (in-school, out-of-school, or overall physical activity). The most successful interventions had the design of a randomized controlled trial, were done over one school year using a multi-component approach integrated into the school curriculum, taught by physical education experts and involving

family members. A common intervention strategy was to increase quantity and/or quality of physical education lessons. The particular role of physical education and its contribution to overall physical activity was the center of attention in the second publication of this dissertation. Even if children's physical activity levels during physical education are relatively low, physical education contributes substantially to overall physical activity.

Due to its nature of being a randomized controlled trial in children with a stringent physical activity program in and outside physical education over one school year and with the inclusion of physical education experts, KISS had excellent pre-conditions for being an effective program. Indeed, the results after nine month of intervention are promising. Compared to controls, children of the intervention group showed 14% reduced cardiovascular risk score, 5% reduced body mass index and skinfold thickness, 6% improved aerobic fitness, 18% higher physical activity levels, and 5-8% higher bone mineral content and bone mineral density. Three years after cessation of the program, intervention children still showed higher aerobic fitness and bone mineral content levels at weight-bearing sites of the skeleton compared to the control group. All other beneficial effects have disappeared.

Even if short-term effects of the intervention are promising, the major key from a public health perspective is whether the effects of the prevention done during childhood will persist into late adolescence and adulthood. Although the maintained effects on aerobic fitness and bone health have considerable impact on public health, most of the beneficial health effects were not maintained three years after the intervention. This indicates that an intervention over one year is too short for maintained overall health effects. Thus, physical activity programs throughout the school years are needed. Our findings contribute to the growing body of evidence that school-based interventions can increase children's health; however the major challenge now, is to find effective implementation strategies to transfer such programs into the real-world setting.

ZUSAMMENFASSUNG

Der Nutzen körperlicher Aktivität für eine gesunde Entwicklung von Kindern und Jugendlichen ist unbestritten. Anderseits kann ein Fehlen von genügender Aktivität während dem Wachstum gesundheitliche Folgen für die Herzkreislauf- und/oder Knochenentwicklung haben, was im späteren Leben zu einer schweren chronischen Erkrankung führen kann. Herzkreislauferkrankungen und Osteoporose sind zwei der weitverbreitetsten chronischen Erkrankungen heutzutage. Der Ursprung beider Erkrankungen scheint in der Kindheit zu liegen, wobei die körperliche Aktivität eine wichtige Rolle in deren Prävention spielt. In Anbetracht dessen, dass sich immer mehr Kinder zu wenig bewegen, steigt die Belastung auf die Gesundheitssysteme weltweit an. Deshalb ist die Entwicklung effektiver Strategien zur Steigerung der körperlichen Aktivität von enormem Public Health Interesse. Die Schule bietet dabei ein optimales Umfeld, da einerseits alle Kinder erreicht werden können und anderseits, die Kinder hier einen Grossteil ihrer Zeit verbringen. Im Fokus dieser Dissertation steht deshalb eine schulbasierte, randomisierte kontrollierte Studie mit dem Ziel, die körperliche Aktivität der Kinder zu steigern und folglich, ihre Herzkreislauf- und Knochengesundheit positiv zu beeinflussen.

Die Kinder- und Jugendsportstudie (KISS) ist eine schulbasierte Bewegungsintervention, welche über eine Dauer von einem Schuljahr durchgeführt wurde. Dabei wurden aus allen Primarschulen der Kantone Aargau und Baselland 28 erste und fünfte Klassen zufällig ausgewählt und in eine Interventionsgruppe (16 Klassen; n=297 Kinder) und eine Kontrollgruppe (12 Klassen; n=205 Kinder) eingeteilt. Das obligatorische, strenge und multidisziplinäre Interventionsprogramm beinhaltete eine tägliche Sportstunde (dabei wurden zwei Lektionen durch ausgebildete Sportlehrer, drei Lektionen durch die normalen Klassenlehrer erteilt), tägliche Bewegungskurzpausen während den akademischen Fächern und Bewegungshausaufgaben. Die Kontrollklassen hatten während dem ganzen Schuljahr lediglich die drei obligatorischen wöchentlichen Sportstunden.

Die Ziele dieser Dissertation waren, nach einem systematischen Überblick bereits existierender Bewegungsinterventionen und einer Quantifizierung Sportstunden spezifischer Aktivität, zu ermitteln, inwiefern KISS das kardiovaskuläre System und die Knochengesundheit kurzfristig beeinflussen kann, und ob diese Effekte auch drei Jahre nach der Intervention noch bestehen.

Der systematische Überblick über bereits existierende Bewegungsinterventionen lieferte tatsächlich vielversprechende Evidenz, dass sich schul-basierte Interventionen zur Bewegungsförderung eignen. Alle der untersuchten Studien der letzten Jahre zeigten, dass sich die Aktivitätslevel der Kinder in mindestens einer Domäne (Aktivität in der Schule, ausserhalb der Schule, oder Gesamtaktivität) erhöhen liessen. Dabei schienen randomisierte kontrollierte Studien mit Kindern, die über die Dauer von einem Schuljahr

liefen, über einen multidisziplinären Ansatz verfügten, fest im Schulkurrikulum verankert wurden, und unter Einbezug von ausgebildeten Sportlehrern und von Familien durchgeführt wurden, besonders effektiv zu sein. Ein bewährter Ansatz war dabei eine Qualitäts- und/oder Quantitätssteigerung der Sportstunde. Die besondere Rolle der Sportstunde in der Bewegungsförderung wurde in der zweiten Publikation dieser Dissertation genauer untersucht. Es konnte dabei gezeigt werden, dass obwohl die Aktivitätslevel in den Sportstunden relativ tief sind, die Sportstunde einen wichtigen Anteil an der Gesamtaktivität der Kinder tragen.

Die KISS-Studie hatte, durch die Erfüllung vieler dieser obengenannten Kriterien, optimale Voraussetzungen wirksam zu sein. Tatsächlich konnten vielversprechende Ergebnisse erreicht werden. Verglichen mit den Kindern der Kontrollgruppe, wiesen die Interventionskinder nach der neunmonatigen Intervention einen 14% tieferen kardiovaskulären Risikoscore, 5% tiefere Übergewichtswerte (Body Mass Index und Hautfaltendicke), eine um 6% erhöhte aerobe Fitness, um 18% erhöhte Aktivitätslevel und eine 5-8%ige Erhöhung von Knochenmineralgehalt und -dichte auf. Drei Jahre nach Programmende verfügten die Interventionskinder immer noch über eine erhöhte aerobe Fitness und einen erhöhten Knochenmineralgehalt, dies vor allem an gewichtstragenden Stellen des Skeletts. Alle anderen positiven Effekte konnten nicht aufrechterhalten werden.

Obwohl die Kurzzeiteffekte der KISS-Studie vielversprechend waren, ist aus einer Public Health Perspektive entscheidend, ob die Effekte eines Präventionsprogramms in der Kindheit auch bis in die späte Adoleszenz und das Erwachsenenalter persistieren. Auch wenn die erreichten Effekte auf die aerobe Fitness und die Knochengesundheit eine erhebliche Bedeutung für die Gesundheit haben, lässt das Verschwinden der anderen Interventionseffekte nach drei Jahren erkennen, dass die Dauer der Intervention über ein Schuljahr wohl zu kurz für langanhaltende Gesundheitseffekte war. Bewegungsförderung sollte sich demnach über die ganze Schulzeit hinweg ziehen. Die Erkenntnisse aus dieser Studie liefern eine zusätzliche Bekräftigung dafür, dass schulbasierte Interventionen die Gesundheit von Kindern verbessern können. Die grösste Herausforderung ist nun jedoch, eine effektive Strategie zu finden, solche Programme in ein reales Umfeld zu transferieren und dort langfristig zu implementieren.

CHAPTER 1

Introduction

INTRODUCTION

Physical activity plays a powerful role in the current public health challenges of rising morbidity and mortality caused by chronic diseases. There is a growing body of evidence that during childhood physical activity – defined as "any bodily movement produced by skeletal muscles that results in energy expenditure[1]" – may improve the development of healthy musculoskeletal (i.e. bones, muscles and joints) and cardiovascular system (i.e. heart and lungs) and the development of neuromuscular awareness (i.e. coordination and movement control). On the other hand, the lack of physical activity during the growing years may lead to several health consequences affecting cardiovascular, metabolic, skeletal and mental health which may result in severe chronic diseases later in life.

As physical inactivity in children and adolescents and its consequences are raising health burdens worldwide, finding effective strategies for increasing children's physical activity is absolutely crucial and of paramount public health importance. This dissertation focuses on a school-based randomized controlled trial aiming at increasing children's physical activity and consequently children's cardiovascular and bone health.

STUDYING PHYSICAL ACTIVITY & HEALTH OUTCOMES IN CHILDREN

According to the World Health Organization, 60% of all global deaths can be attributed to chronic diseases[2]. About 3.2 million deaths annually can be attributed to insufficient physical activity representing the fourth leading risk factor for global mortality following hypertension, tobacco use and high blood glucose.

Figure 1.1 shows the known relationships of physical activity and health outcomes in children. Known associations exist between physical activity and aerobic fitness (for review see[3]), overweight (for review see[4]), mental health (for review see[5]), cardiovascular health (for review see[6]) and bone health (for review see[7]). However, studying morbidity and mortality due to chronic diseases is limited to the adult population since these endpoints do usually not occur during childhood, although first pre-pathological processes of these diseases may already start in childhood. Studying chronic diseases in children does therefore not include the assessment of disease, but tries to identify intermediate health outcomes such as low bone mass or cardiovascular risk factors. Yet, these outcomes are indirect parameters and it remains unclear whether they predict the development of a disease later in life. Nevertheless, several studies could show that these indirect parameters track from childhood into older ages[8-10]. As inactive lifestyle also tracks into adulthood[11-13], one could estimate that without intervening, an inactive child with high cardiovascular risk or low bone mass is more likely to develop a severe cardiovascular disease or osteoporosis later in life than an active child with normal intermediate health outcomes.

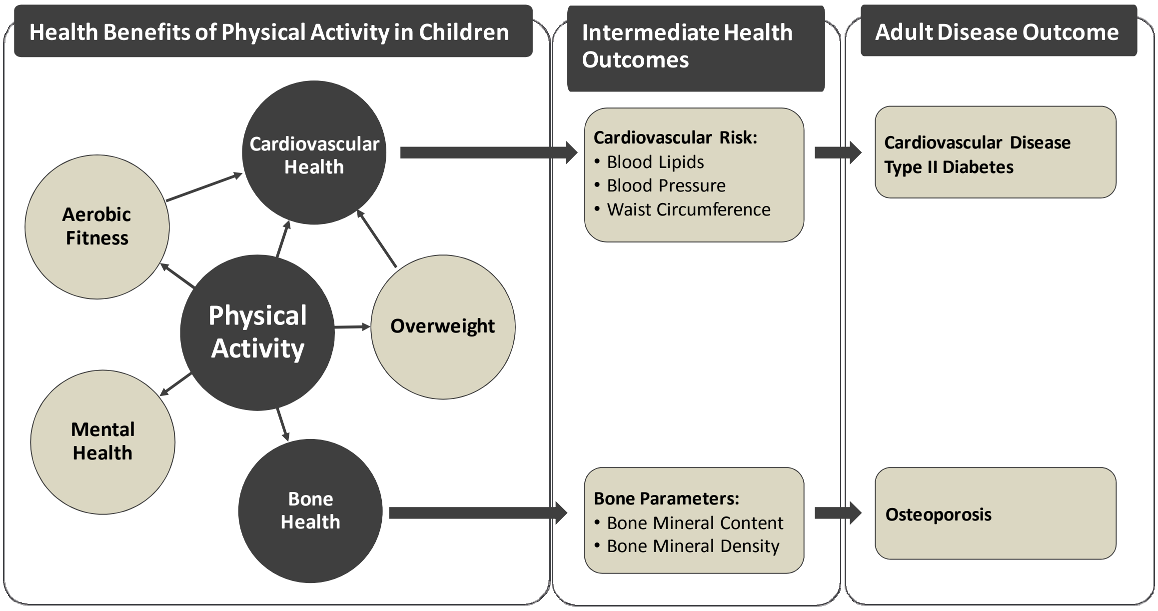

Figure 1.1 - Health benefits of childhood physical activity and its consequences later in life.

PHYSICAL ACTIVITY DURING CHILDHOOD

Epidemiological aspects of physical activity

While there is clear evidence that childhood overweight has increased substantially over the last decades(14), time trends in children's physical activity levels are not well documented. To examine this issue it would be necessary to repeat physical activity measurements in representative samples of children over several years. Previous studies have often used self-report questionnaires to assess physical activity, but this method has been widely replaced by objective measurement tools, as for example accelerometers. Compared to self-report questionnaires which are known to have a limitation in their accuracy particularly in children(15), accelerometers have a wide range of advantages. They are able to accurately and objectively measure volume, pattern, frequency, intensity and duration of children's physical activity in large population samples. This shift in method and the low correlation of the two methods(16) make it difficult to detect secular trends.

A recent review article(17) summarized that there is no clear evidence that children's physical activity levels have declined over the last two decades. In contrast to this, another review(18) found that at least in well-defined contexts such as active transport, sport participation or physical education, today's children are less active than children from former generations. Even without clear evidence for time trends in physical activity behavior over the last decades, it was stated that for the majority of children, additional activities were needed to meet the physical activity recommendations for a healthy lifestyle[17, 19] including normal body weight.

Children's physical activity guidelines recommend that children should accumulate at least 60 minutes of moderate and vigorous physical activity on at least five days of the week[20]. However, the World Health Organization lately published global guidelines for children's physical activity levels recommending that 60 minutes of at least moderate intensity should be accumulated *in addition* to the daily life activities[21]. These 60-minutes-guidelines were based on intervention studies and self-reported physical activity in observational studies not taking into account the 'background' physical activity of the children. The use of the more accurate accelerometers now allows determining a more precise dose-response relationship of physical activity and health outcomes. Physical activity levels of a minimum of 90 minutes per day of at least moderate intensity have been shown to prevent clustering of cardiovascular risk factors which is in line with the World Health Organization's recommendations[22].

The role of the school setting

Children spend about half of their waking hours in school. Thus, the school setting plays an important role in providing and promoting physical activity in children[23, 24]. From a public health aspect, an important advantage of the school setting is the fact that every child, irrespective of its socioeconomic background, ethnicity and/or health status can be reached.

Although a school day provides several opportunities for being active, such as active commuting, recess time and after school programs, physical education is of prime importance promoting children's physical activity. Despite this, physical activity levels during physical education lessons have been shown to be relatively low[25]. However, until yet it remains unclear to what extend physical education contributes to overall physical activity and whether school-based physical activity interventions aiming at increasing children's physical activity levels are successful. With only about one third of the physical education time spent in at least moderate intensity, the potential to intervene on the level of physical education becomes evident.

CARDIOVASCULAR HEALTH

With 17 million annual deaths worldwide, cardiovascular diseases account for most deaths caused by non-communicable diseases[2]. Therefore prevention and in particular primary prevention is of significant public health interest. In adults, a composite cardiovascular risk score has been defined by the so called metabolic syndrome. It is defined as a combination of hypertriglyceridemia, low high-density lipoprotein-cholesterol level, high fasting glucose level, excessive waist circumference and hypertension[26]. Adults with three or more of these abnormalities are at higher risk for developing atherosclerotic cardiovascular disease[27] or type II diabetes[28]. A clustering of cardiovascular risk factors is based on the fact that the risk factors tend to aggregate in some individuals and are not independently distributed in the population[29]. Although rare in normal weight children, the metabolic syndrome exists in 50% of severely obese adolescents[30]. Nevertheless, metabolic syndrome characteristics with single elevated cardiovascular risk factors exist in 3-14% of all children and adolescents, underlying the atherosclerotic origin[30-33]. The variation in prevalence among the different studies might be caused by different definitions of the metabolic syndrome characteristics in children. To date, there is no clear consensus of the parameters included into the definition of the cardiovascular risk in children and adolescents nor the cut-offs for single factors. The use of a clustered risk score (summarized z-score of multiple risk factors) became widely accepted[22, 31, 34]. This continuous composite score is an elegant way of defining the cumulative cardiovascular burden of known single risk factors without the questionable need of defining an exact cut-off. Factors included into the score usually comprise an obesity parameter (waist circumference, body mass index or skinfold thickness), triglycerides, fasting glucose, high-density lipoprotein-cholesterol and blood pressure.

Tracking of cardiovascular risk factors into adulthood

A summary of four prospective cohort studies that have followed up individuals from childhood to adulthood documented that cardiovascular risk factors measured after the age of nine years have showed significant associations between childhood risk exposure and increased adult carotid artery intimamedia thickness - a marker of subclinical atherosclerosis[35]. One of these prospective studies, the Bogalusa Heart Study indicated that the individual risk factors track from childhood into the adult years[8, 36, 37]. The assessment of cardiovascular risk factors during childhood is important, as the clustered appearance of these factors is directly related to the existence of early atherosclerosis in aorta and coronary arteries[29] or increased intimamedia thickness as adults[35].

The causes of increased cardiovascular risk are multi-factorial. Besides genetic preposition and intrauterine factors, modifiable lifestyle behaviours play an important role[38]. Consequently, intervening on the level of behaviour at a young age might be a promising strategy in prevention of cardiovascular disease. As targeting obesity and nutrition, which is often associated with restriction and prohibition, has been shown to be often ineffective[39], since it has to be done with major involvement of the parents, the focus on physical activity behaviour may be more positive and effective, especially in school.

Associations between physical activity and cardiovascular risk factors

Two recent review articles focussed the question whether physical activity is associated with clustered cardiovascular risk in children and adolescents[6, 31]. While data from studies with self-reported physical activity were inconclusive regarding their relationship to cardiovascular risk, accelerometer data provide more conclusive findings. A large multicenter cross-sectional survey in 9- and 15-years old children reported a graded negative association of accelerometer-derived physical activity and clustered cardiovascular risk score(22). Thereby, the risk for having a high cardiovascular risk score was raised in low active children compared to the most active children. In their study, 90 minutes of moderate and vigorous physical activity in 15-years old children and 115 minutes in 9-years old, respectively, were needed to prevent clustering of cardiovascular risk factors. In a subsample of the study population, Brage et al.(40) found the same negative association between physical activity and clustered cardiovascular risk, even after adjustment for potential confounding factors as i.e. aerobic fitness and adiposity, indicating an even stronger relationship in children with low aerobic fitness. In line with this study, we could find in our study sample, that low aerobic fitness and low physical activity were independently related to an increase in the cardiovascular risk score(41). The fact that physical activity is negatively related to cardiovascular risk independently of aerobic fitness could have substantial public health implications, since it might be easier to increase physical activity than aerobic fitness.

The negative associations between physical activity and clustered cardiovascular risk described above all derived from cross-sectional studies, questioning causality. However, knowledge from longitudinal or interventional studies is very limited. Most physical activity intervention studies aiming at reducing cardiovascular risk have been done in overweight or obese children, and not in a healthy, representative population(42, 43). Further, there is a lack of well-designed controlled trials. Although, most of the reported studies have been successful in reducing cardiovascular risk factors in a clinical population at risk, it remains unclear whether a general physical activity intervention program in healthy children may also lead to a reduced clustered cardiovascular risk and whether these effects persist after cessation of the program.

Aerobic fitness as determinant of cardiovascular health

Aerobic fitness may be defined as the ability to deliver oxygen to the muscles and to utilize it to generate energy to support muscle activity during exercise(3). Aerobic fitness is known to be a strong predictor for cardiovascular disease in adulthood(44-47). Several studies in children and adolescents showed that low aerobic fitness is associated with cardiovascular risk factors(48-50). This relationship is independent of physical activity and obesity, revealing that aerobic fitness may play a protective role for all levels of obesity and physical activity(41, 48, 51, 52).

BONE HEALTH

Osteoporosis is another major non-communicable disease affecting every third woman and every fifth men above the age of 50 years, i.e. they will suffer from an osteoporotic fracture during their remaining lifetime(53, 54). Osteoporosis may be defined as a reduced bone strength and disruption of bone architecture which results in increased bone fragility and increased fracture risk(55). Most fractures occur at the hip, the vertebrae, and the distal radius. Hip fractures represent the most serious fracture site because they are related to longer hospitalization, significant pain, reduced morbidity, disability and excessed mortality(55-57). Data from Switzerland showed that the total estimated costs due to osteoporosis and related fractures in 2000 were 357 million CHF(58), mainly due to fracture-related hospitalization(55). Of these, hip fractures accounted for approximately half of the costs(58). Estimations showed that due to the increased life expectancy of the population, the proportion of the Swiss population over 50 years of age will increase from one third to half of the whole population until 2050(59). Certainly, this will lead to more individuals suffering from osteoporotic fractures and considerably raising costs of healthcare related to fractures.

The importance of peak bone mass

Even if osteoporotic fractures are rare before the age of 50 years, primary prevention should start in childhood as 60% of the risk of osteoporosis can be explained by the modifiable amount of bone mass acquired by early adulthood(60). The skeletal development starts during fetal life and reaches a plateau (the so-called peak bone mass) by the end of the second decade or early in the third decade(61). The years around puberty are meant to be the crucial period for the accrual of bone mass and formation of bone structure, since 33 to 46% of the early adult bone mass is achieved during the five years around the time of peak high velocity which corresponds with the pubertal development(61). After achieving peak bone mass, bone mass remains relatively stable throughout the adult years until the age-related bone loss prevails with ageing(62, 63). It is estimated, that the amount of bone mass accrued during the years around peak high velocity represents double the amount of the age-related bone mass loss between 50 and 80 years of age(61, 63).

Thus, maximizing peak bone mass during the growing years is recognized as an essential strategy for preventing osteoporosis later in life. While 60 to 80% of the variance in peak bone mass is determined by genetic factors(64, 65), the remaining variance is explained by environmental factors such as nutrition (calcium and protein intake), hormonal status (sex hormones, vitamin D, growth hormones, and insulin-like growth factor), and physical loading(66). Importantly, these remaining environmental factors are modifiable and may be influenced by interventions.

Functional adaptation of bone to mechanical loading

Bone is a highly dynamic tissue which adapts to functional needs. Observations of bone's response to mechanical loading have a long tradition, starting with Galileo Galilei in the 17th century. A central hypothesis is the so-called "Wolff's law" by Julius Wolff who stated that bone changes its shape and internal structure in response to stresses acting on it(67). It was extended by Harald Frost in the "mechanostat theory"(68, 69) where bone adapts its strength in response to strain thresholds that turn the bone building process on or off. The mechanism of how bone cells response to mechanical loading is called mechanotransduction which includes four steps: First, bone tissue is deformed at the site where loading acts. This deformation creates pressure within the bone canaliulae and interstitial spaces and causes tissue fluid to move (see Figure 1.2). In a second step, the moving tissue fluid creates a fluid shear stress which is detected by proteins in the cell membranes. This leads to a transduction of the mechanical signal into a biochemical response, which can then initiate the third and fourth step where the biochemical signal is transducted to the effector cell that will initiate formation or resorption of bone cell tissue(70, 71).

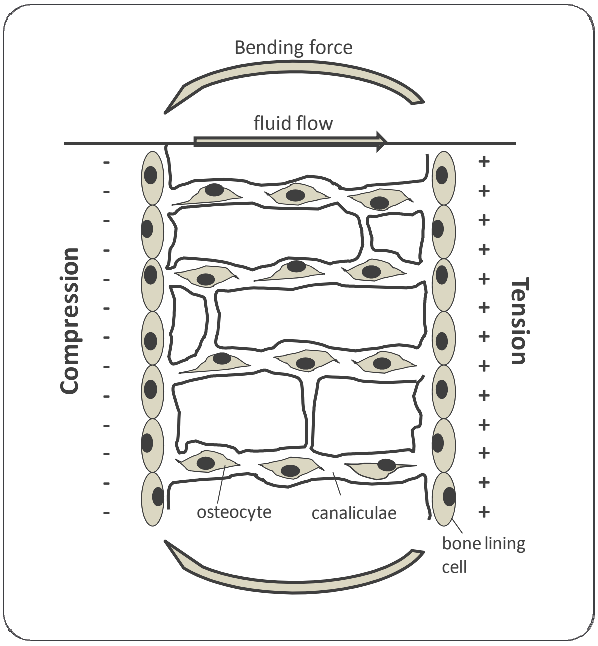

Figure 1.2 Bending forces lead to a deformation and causes tissue fluid in the canaliculae (adapted from Duncan et al. 1995 Calcif Tissue Int)

Measurement of bone strength

Bone strength can be defined as the ability of bone to withstand an applied stress without fracturing. This ability depends on bone mass and bone micro architecture(72, 73). Bone mass is thereby basically defined by the bone material composition which is the amount of mineral, mainly calcium hydroxyapatite, embedded in the collagen matrix of bone. Since there is no possibility to directly measure bone strength or failure load in vivo, bone strength is estimated by measuring bone mineral mass or areal bone mineral density (mineral mass per area). As bone mineral mass and density is not directly measurable by noninvasive techniques, it has to be estimated from bone imaging techniques, e.g. by dual-energy X-ray absorptiometry (DXA). DXA is considered to be the gold standard in assessing bone density(74) in both, adults and children. Compared to other imaging techniques, the radiation exposure is relatively low and the reproducibility of the measurements at different sites of the growing skeleton has been shown to be satisfying(75). Further advantages of DXA are the short scan time which is in children of particular interest, and the widespread availability as it is probably the technique most widely used. Nevertheless, it has to be kept in mind that DXA has its limitations, such as being an indirect measuring method and as not measuring neither structural nor real volumetric aspects of bone. However, both DXA-derided bone mineral content and bone mineral density are known to predict fracture risk at a population level(76, 77).

Osteogenic physical activity

The skeleton's response to mechanical loading depends on the strain magnitude, strain rate, strain distribution, and number of load repetitions(78). Therefore, influencing bone mass by physical activity requires specific loading characteristics. Loading can either act as load from impact with the ground (ground reaction forces) or load from skeletal muscle contraction (muscle forces or muscle-joint-forces)(79). However, since both loads often occur in combination, it is still unclear, which of these two sources has the higher impact on bone building(79-82).

Since bone tissue is of viscoelastic character, activation of new bone formation requires a certain threshold level and strain rate. Activities with high strain rates, i.e. jumping activities are more osteogenic than activities where a strain magnitude is constant over a longer time period (i.e. isometric exercises)(83, 84). Furthermore, animal studies showed that only few loading cycles are needed to stimulate bone formation(85, 86) and short, intense loading interspersed with recovery periods(87) are needed to optimize bone formation stimulation, leading to the fact that high-impact exercises broken up into shorter bouts with rest periods between are thought to have the best osteogenic effect. However, the optimal exercise description including the amount of forces required and the relationship of dose and response of bone to physical loading has still to be explored.

Physical activity and bone in childhood and adolescence

Studies in animals and humans showed clear evidence that the growing skeleton has a greater potential to adapt to loading than the bone of adults(88, 89). Although, physically active subjects generally have higher muscle and bone mass, irrespective of age(73). An excellent opportunity to examine the relationship between physical loading and bone mass are unilateral sporting activities, such as i.e. racket sports. The fact that the load exposure is only unilateral provides the advantage of having a perfect internal reference of the non-dominant site that controls for all confounders other than exercise. Differences between the dominant and non-dominant arm of racket players have been shown to be greatest in players who started playing before puberty[(90)]. However, activities like this are not necessarily comparable to physical activity of a more public health related aspect. Though, cross-sectional studies have also shown that there are positive associations between children's bone mass and general physical activity levels[(91, 92)].

The longitudinal Saskatchewan Pediatric Bone Mineral Accrual Study provides optimal knowledge about how higher physical activity levels during adolescence is associated with greater bone mass in the early adult years[(93)]. Active adolescents showed compared to their inactive or moderately active counterparts during adolescence 8 to 15% higher bone mineral content levels. These effects could be maintained into early adulthood, where active adolescents still had 8 to 10% higher bone mineral content levels[(93)]. The results of a second large longitudinal study, the Amsterdam Growth and Health Longitudinal Study follow the same line: Physical activity during the adolescent years was positively related to bone mineral density of the weight-bearing sites at adult age[(94, 95)]. Interestingly, bone mineral density at non-weight bearing sites was not related to physical activity during adolescence.

The effect of physical loading interventions on bone parameters during childhood and adolescence was center of attention in several reviews[(7, 89, 96-98)]. They all showed promising effects of the interventions on bone parameters. However, the need of more well-designed and controlled investigations are required. Indeed, there are a few well-designed randomized controlled trials which are briefly described here:

"Action Schools! BC", a Canadian project by a research group of Vancouver[(99)], is an example of a well-designed randomized controlled trial which is besides being implemented in an impressive manner. One part of this multi-component intervention program addressed bone health of the children and adolescents. "Bounce at the Bell" program[(100)] was implemented into the Action Schools! BC project which means that children had to perform short bouts of high impact jumps three times a day for a few minutes over a time period of 11 months. The program was effective in increasing tibial bone strength[(101, 102)].

Fuchs et al.[(103)] did a jumping program in young, prepubertal children. Children in the intervention group had to jump off from a box 100 times, three times per week over 7 months. They reported significantly increased bone mineral content and bone mineral density levels of about 2.0 to 4.5% compared to control children. Unique in this intervention, the authors have quantified the ground reaction forces associated with jumping.

Newer intervention studies with less targeted loading programs (i.e. an augmented number of physical education lessons or more general physical activity) also showed promising results, however they have the limitation of not being randomized trials[104-108].

In summary, most of the randomized controlled intervention studies were clearly targeted on bone loading and included i.e. drop jumps from a defined box[103] or a defined number of jumps[100, 102]. Such intervention studies provide promising results reporting 1 to 8% higher bone mass and strength in intervention children (see reviews[89, 97]). However, general physical activity based public health interventions in community real-life situations that focus not only on bone but also on other positive health aspects like aerobic fitness or cardiovascular risk factors in a large representative child population are sparse. Until today, it is unclear whether a general physical activity program in school could achieve similar benefits on bone mass than the existing tailored loading interventions.

Long-term effects of physical activity on bone health

As mentioned above, physical activity during childhood and adolescence has been shown to positively influence the development of a higher peak bone mass at the early adult age[93]. However, the crucial question is whether these effects persist into senescence to reduce fracture risk later in life. Due to logistic reasons, there has never been and probably will never be a randomized controlled trial examining the effects of a physical activity intervention during childhood on bone fracture risk in older age. Thus, this knowledge has to derive from animal studies, retrospective human studies or mathematical model calculations. Animal studies and studies on humans who have retired from sports revealed inconclusive evidence of sustained bone mass after sport cessation[109-111]. In general, it seems that structural adaptations of bone persist after sport cessation[109, 112]. As bone structure might be more important to overall bone strength than bone mineral mass and density, fracture risk might be reduced in serenity despite the negative findings from studies measuring bone mass. This is supported by an epidemiological study in former soccer and ice hockey players revealed that the fracture prevalence at the age of 50 years and more was significantly lower compared to controls who did not participate in sport[113]. Calculations deriving from mathematical models further emphasize the importance of a high peak bone mass in reducing fracture risk later in life. It was calculated that a 10% increase in peak bone mass would delay the onset of osteoporosis by 13 years[114]. Thus, achieving optimal peak bone mass might be seen as a paramount opportunity in the prevention of osteoporosis.

REFERENCES

(1) Caspersen CJ, Powell KE, Christenson GM. Physical Activity, Exercise, and Physical Fitness: Definitions and Distinctions for Health-Related Research. Public Health Rep. 1985; 100(2): 126.

(2) World Health Organization. Global Status Report on Noncommunicable Diseases 2010. Geneva: World Health Organization; 2011.

(3) Armstrong N, Tomkinson G, Ekelund U. Aerobic Fitness and Its Relationship to Sport, Exercise Training and Habitual Physical Activity During Youth. Br J Sports Med. 2011; 45(11): 849.

(4) Hills AP, Andersen LB, Byrne NM. Physical Activity and Obesity in Children. Br J Sports Med. 2011; 45(11): 866.

(5) Biddle SJ, Asare M. Physical Activity and Mental Health in Children and Adolescents: A Review of Reviews. Br J Sports Med. 2011; 45(11): 886.

(6) Andersen LB, Riddoch C, Kriemler S, Hills A. Physical Activity and Cardiovascular Risk Factors in Children. Br J Sports Med. 2011; 45(11): 871.

(7) Boreham CA, McKay HA. Physical Activity in Childhood and Bone Health. Br J Sports Med. 2011; 45(11): 877.

(8) Nicklas TA, von Duvillard SP, Berenson GS. Tracking of Serum Lipids and Lipoproteins from Childhood to Dyslipidemia in Adults: The Bogalusa Heart Study. Int J Sports Med. 2002; 23 Suppl 1: S39.

(9) Foley S, Quinn S, Jones G. Tracking of Bone Mass from Childhood to Adolescence and Factors That Predict Deviation from Tracking. Bone. 2009; 44(5): 752.

(10) Budek AZ, Mark T, Michaelsen KF, Molgaard C. Tracking of Size-Adjusted Bone Mineral Content and Bone Area in Boys and Girls from 10 to 17 Years of Age. Osteoporos Int. 2010; 21(1): 179.

(11) Craigie AM, Lake AA, Kelly SA, Adamson AJ, Mathers JC. Tracking of Obesity-Related Behaviours from Childhood to Adulthood: A Systematic Review. Maturitas. 2011; 70(3): 266.

(12) Telama R. Tracking of Physical Activity from Childhood to Adulthood: A Review. Obes Facts. 2009; 2(3): 187.

(13) Malina RM. Tracking of Physical Activity and Physical Fitness across the Lifespan. Res Q Exerc Sport. 1996; 67(3 Suppl): S48.

(14) Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of Overweight and Obesity in the United States, 1999-2004. JAMA. 2006; 295(13): 1549.

(15) Sallis JF. Self-Report Measures of Children's Physical Activity. J Sch Health. 1991; 61: 215.

(16) Corder K, Ekelund U, Steele RM, Wareham NJ, Brage S. Assessment of Physical Activity in Youth. J Appl Physiol. 2008; 105(3): 977.

(17) Ekelund U, Tomkinson G, Armstrong N. What Proportion of Youth Are Physically Active? Measurement Issues, Levels and Recent Time Trends. Br J Sports Med. 2011; 45(11): 859.

(18) Dollman J, Norton K, Norton L. Evidence for Secular Trends in Children's Physical Activity Behaviour. Br J Sports Med. 2005; 39(12): 892.

(19) Ruiz JR, Ortega FB, Martinez-Gomez D, Labayen I, Moreno LA, De Bourdeaudhuij I, et al. Objectively Measured Physical Activity and Sedentary Time in European Adolescents: The Helena Study. Am J Epidemiol. 2011; 174(2): 173.

(20) Strong WB, Malina RM, Blimkie CJ, Daniels SR, Dishman RK, Gutin B, et al. Evidence Based Physical Activity for School-Age Youth. J Pediatr. 2005; 146(6): 732.

(21) World Health Organization. Global Recommendations on Physical Activity for Health. Geneva: WHO; 2010.

(22) Andersen LB, Harro M, Sardinha LB, Froberg K, Ekelund U, Brage S, et al. Physical Activity and Clustered Cardiovascular Risk in Children: A Cross-Sectional Study (the European Youth Heart Study). Lancet. 2006; 368(9532): 299.

(23) Pate RR, O'Neill JR. Summary of the American Heart Association Scientific Statement: Promoting Physical Activity in Children and Youth: A Leadership Role for Schools. J Cardiovasc Nurs. 2008; 23(1): 44.

(24) Pate RR, Davis MG, Robinson TN, Stone EJ, McKenzie TL, Young JC. Promoting Physical Activity in Children and Youth: A Leadership Role for Schools: A Scientific Statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism (Physical Activity Committee) in Collaboration with the Councils on Cardiovascular Disease in the Young and Cardiovascular Nursing. Circulation. 2006; 114(11): 1214.

(25) Fairclough SJ, Stratton G. A Review of Physical Activity Levels During Elementary School Physical Education. J Teach Phys Educ. 2006; 25(2): 239.

(26) Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, et al. Harmonizing the Metabolic Syndrome: A Joint Interim Statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. Circulation. 2009; 120(16): 1640.

(27) Isomaa B, Almgren P, Tuomi T, Forsen B, Lahti K, Nissen M, et al. Cardiovascular Morbidity and Mortality Associated with the Metabolic Syndrome. Diabetes Care. 2001; 24(4): 683.

(28) Haffner SM, Valdez RA, Hazuda HP, Mitchell BD, Morales PA, Stern MP. Prospective Analysis of the Insulin-Resistance Syndrome (Syndrome X). Diabetes. 1992; 41(6): 715.

(29) Berenson GS, Srinivasan SR, Bao W, Newman WP, 3rd, Tracy RE, Wattigney WA. Association between Multiple Cardiovascular Risk Factors and Atherosclerosis in Children and Young Adults. The

Bogalusa Heart Study. N Engl J Med. 1998; 338(23): 1650.
(30) Weiss R, Dziura J, Burgert TS, Tamborlane WV, Taksali SE, Yeckel CW, et al. Obesity and the Metabolic Syndrome in Children and Adolescents. N Engl J Med. 2004; 350(23): 2362.
(31) Steele RM, Brage S, Corder K, Wareham NJ, Ekelund U. Physical Activity, Cardiorespiratory Fitness, and the Metabolic Syndrome in Youth. J Appl Physiol. 2008; 105(1): 342.
(32) de Ferranti SD, Gauvreau K, Ludwig DS, Neufeld EJ, Newburger JW, Rifai N. Prevalence of the Metabolic Syndrome in American Adolescents: Findings from the Third National Health and Nutrition Examination Survey. Circulation. 2004; 110(16): 2494.
(33) Jolliffe CJ, Janssen I. Development of Age-Specific Adolescent Metabolic Syndrome Criteria That Are Linked to the Adult Treatment Panel Iii and International Diabetes Federation Criteria. J Am Coll Cardiol. 2007; 49(8): 891.
(34) Eisenmann JC. On the Use of a Continuous Metabolic Syndrome Score in Pediatric Research. Cardiovasc Diabetol. 2008; 7: 17.
(35) Juonala M, Magnussen CG, Venn A, Dwyer T, Burns TL, Davis PH, et al. Influence of Age on Associations between Childhood Risk Factors and Carotid Intima-Media Thickness in Adulthood: The Cardiovascular Risk in Young Finns Study, the Childhood Determinants of Adult Health Study, the Bogalusa Heart Study, and the Muscatine Study for the International Childhood Cardiovascular Cohort (I3c) Consortium. Circulation. 2010; 122(24): 2514.
(36) Berenson GS. Childhood Risk Factors Predict Adult Risk Associated with Subclinical Cardiovascular Disease. The Bogalusa Heart Study. Am J Cardiol. 2002; 90(10C): 3L.
(37) Srinivasan SR, Myers L, Berenson GS. Predictability of Childhood Adiposity and Insulin for Developing Insulin Resistance Syndrome (Syndrome X) in Young Adulthood: The Bogalusa Heart Study. Diabetes. 2002; 51(1): 204.
(38) Steinberger J, Daniels SR, Eckel RH, Hayman L, Lustig RH, McCrindle B, et al. Progress and Challenges in Metabolic Syndrome in Children and Adolescents: A Scientific Statement from the American Heart Association Atherosclerosis, Hypertension, and Obesity in the Young Committee of the Council on Cardiovascular Disease in the Young; Council on Cardiovascular Nursing; and Council on Nutrition, Physical Activity, and Metabolism. Circulation. 2009; 119(4): 628.
(39) Waters E, de Silva-Sanigorski A, Hall BJ, Brown T, Campbell KJ, Gao Y, et al. Interventions for Preventing Obesity in Children. Cochrane Database Syst Rev. 2011; 12: CD001871.
(40) Brage S, Wedderkopp N, Ekelund U, Franks PW, Wareham NJ, Andersen LB, et al. Features of the Metabolic Syndrome Are Associated with Objectively Measured Physical Activity and Fitness in Danish Children: The European Youth Heart Study (Eyhs). Diabetes Care. 2004; 27(9): 2141.
(41) Kriemler S, Manser-Wenger S, Zahner L, Braun-Fahrlander C, Schindler C, Puder JJ. Reduced Cardiorespiratory Fitness, Low Physical Activity and an Urban Environment Are Independently Associated with Increased Cardiovascular Risk in Children. Diabetologia. 2008; 51(8): 1408.
(42) Guinhouya BC, Samouda H, Zitouni D, Vilhelm C, Hubert H. Evidence of the Influence of Physical Activity on the Metabolic Syndrome and/or on Insulin Resistance in Pediatric Populations: A Systematic Review. Int J Pediatr Obes. 2011; 6(5-6): 361.
(43) Gutin B, Owens S. The Influence of Physical Activity on Cardiometabolic Biomarkers in Youths: A Review. Pediatr Exerc Sci. 2011; 23(2): 169.
(44) Lee CD, Blair SN, Jackson AS. Cardiorespiratory Fitness, Body Composition, and All-Cause and Cardiovascular Disease Mortality in Men. Am J Clin Nutr. 1999; 69(3): 373.
(45) Blair SN, Goodyear NN, Gibbons LW, Cooper KH. Physical Fitness and Incidence of Hypertension in Healthy Normotensive Men and Women. JAMA. 1984; 252(4): 487.
(46) Sandvik L, Erikssen J, Thaulow E, Erikssen G, Mundal R, Rodahl K. Physical Fitness as a Predictor of Mortality among Healthy, Middle-Aged Norwegian Men. N Engl J Med. 1993; 328(8): 533.
(47) Fogelholm M. Physical Activity, Fitness and Fatness: Relations to Mortality, Morbidity and Disease Risk Factors. A Systematic Review. Obes Rev. 2010; 11(3): 202.
(48) Eisenmann JC, Katzmarzyk PT, Perusse L, Tremblay A, Despres JP, Bouchard C. Aerobic Fitness, Body Mass Index, and Cvd Risk Factors among Adolescents: The Quebec Family Study. Int J Obes. 2005; 29(9): 1077.
(49) Anderssen SA, Cooper AR, Riddoch C, Sardinha LB, Harro M, Brage S, et al. Low Cardiorespiratory Fitness Is a Strong Predictor for Clustering of Cardiovascular Disease Risk Factors in Children Independent of Country, Age and Sex. Eur J Cardiovasc Prev Rehabil. 2007; 14(4): 526.
(50) Froberg K, Andersen LB. Mini Review: Physical Activity and Fitness and Its Relations to Cardiovascular Disease Risk Factors in Children. Int J Obes. 2005; 29 Suppl 2: S34.
(51) Ekelund U, Anderssen SA, Froberg K, Sardinha LB, Andersen LB, Brage S. Independent Associations of Physical Activity and Cardiorespiratory Fitness with Metabolic Risk Factors in Children: The European Youth Heart Study. Diabetologia. 2007; 50(9): 1832.
(52) Eisenmann JC, Welk GJ, Wickel EE, Blair SN. Combined Influence of Cardiorespiratory Fitness and Body Mass Index on Cardiovascular Disease Risk Factors among 8-18 Year Old Youth: The Aerobics Center Longitudinal Study. Int J Pediatr Obes. 2007; 2(2): 66.
(53) Lippuner K, Johansson H, Kanis JA, Rizzoli R. Remaining Lifetime and Absolute 10-Year

Probabilities of Osteoporotic Fracture in Swiss Men and Women. Osteoporos Int. 2009; 20(7): 1131.
(54) Johnell O, Kanis JA. An Estimate of the Worldwide Prevalence and Disability Associated with Osteoporotic Fractures. Osteoporos Int. 2006; 17(12): 1726.
(55) Ström O, Borgström F, Kanis JA, Compston J, Cooper C, McCloskey EV, et al. Osteoporosis: Burden, Health Care Provision and Opportunities in the Eu. Arch Osteoporos. 2011; 6(1-2): 59.
(56) Johnell O, Kanis J. Epidemiology of Osteoporotic Fractures. Osteoporos Int. 2005; 16 Suppl 2: S3.
(57) Keene GS, Parker MJ, Pryor GA. Mortality and Morbidity after Hip Fractures. Br Med J. 1993; 307(6914): 1248.
(58) Lippuner K, Golder M, Greiner R. Epidemiology and Direct Medical Costs of Osteoporotic Fractures in Men and Women in Switzerland. Osteoporos Int. 2005; 16 Suppl 2: S8.
(59) Bundesamt für Statistik (BfS). Szenarien Zur Bevölkerungsentwicklung Der Schweiz. 2005–2050. Neuchatel; 2006.
(60) Hui SL, Slemenda CW, Johnston CC, Jr. The Contribution of Bone Loss to Postmenopausal Osteoporosis. Osteoporos Int. 1990; 1(1): 30.
(61) Baxter-Jones AD, Faulkner RA, Forwood MR, Mirwald RL, Bailey DA. Bone Mineral Accrual from 8 to 30 Years of Age: An Estimation of Peak Bone Mass. J Bone Miner Res. 2011; 26(8): 1729.
(62) Ensrud KE, Palermo L, Black DM, Cauley J, Jergas M, Orwoll ES, et al. Hip and Calcaneal Bone Loss Increase with Advancing Age: Longitudinal Results from the Study of Osteoporotic Fractures. J Bone Miner Res. 1995; 10(11): 1778.
(63) Arlot ME, Sornay-Rendu E, Garnero P, Vey-Marty B, Delmas PD. Apparent Pre- and Postmenopausal Bone Loss Evaluated by Dxa at Different Skeletal Sites in Women: The Ofely Cohort. J Bone Miner Res. 1997; 12(4): 683.
(64) Bonjour JP, Chevalley T, Rizzoli R, Ferrari S. Gene-Environment Interactions in the Skeletal Response to Nutrition and Exercise During Growth. Med Sport Sci. 2007; 51: 64.
(65) Davies JH, Evans BA, Gregory JW. Bone Mass Acquisition in Healthy Children. Arch Dis Child. 2005; 90(4): 373.
(66) Rizzoli R, Bianchi ML, Garabedian M, McKay HA, Moreno LA. Maximizing Bone Mineral Mass Gain During Growth for the Prevention of Fractures in the Adolescents and the Elderly. Bone. 2010; 46(2): 294.
(67) Wolff J. Das Gesetz Der Transformation Der Knochen. Berlin: Hirschwald; 1892.
(68) Frost HM. Bone "Mass" and the "Mechanostat": A Proposal. Anat Rec. 1987; 219(1): 1.
(69) Frost HM. From Wolff's Law to the Mechanostat: A New "Face" of Physiology. J Orthop Sci. 1998; 3(5): 282.
(70) Turner CH, Pavalko FM. Mechanotransduction and Functional Response of the Skeleton to Physical Stress: The Mechanisms and Mechanics of Bone Adaptation. J Orthop Sci. 1998; 3(6): 346.
(71) Duncan RL, Turner CH. Mechanotransduction and the Functional Response of Bone to Mechanical Strain. Calcif Tissue Int. 1995; 57(5): 344.
(72) Currey JD. The Many Adaptations of Bone. J Biomech. 2003; 36(10): 1487.
(73) Kontulainen SA, Hughes JM, Macdonald HM, Johnston JD. The Biomechanical Basis of Bone Strength Development During Growth. Med Sport Sci. 2007; 51: 13.
(74) World Health Organization. Assessment of Fracture Risk and Its Application to Screening for Postmenopausal Osteoporosis. Report of a Who Study Group. World Health Organ Tech Rep Ser. 1994; 843: 1.
(75) Bonjour JP, Chevalley T, Ammann P, Slosman D, Rizzoli R. Gain in Bone Mineral Mass in Prepubertal Girls 3.5 Years after Discontinuation of Calcium Supplementation: A Follow-up Study. Lancet. 2001; 358(9289): 1208.
(76) Johnell O, Kanis JA, Oden A, Johansson H, De Laet C, Delmas P, et al. Predictive Value of Bmd for Hip and Other Fractures. J Bone Miner Res. 2005; 20(7): 1185.
(77) Melton LJ, 3rd, Crowson CS, O'Fallon WM, Wahner HW, Riggs BL. Relative Contributions of Bone Density, Bone Turnover, and Clinical Risk Factors to Long-Term Fracture Prediction. J Bone Miner Res. 2003; 18(2): 312.
(78) Lanyon LE. Using Functional Loading to Influence Bone Mass and Architecture: Objectives, Mechanisms, and Relationship with Estrogen of the Mechanically Adaptive Process in Bone. Bone. 1996; 18(1 Suppl): 37S.
(79) Beck BR. Muscle Forces or Gravity--What Predominates Mechanical Loading on Bone? Introduction. Med Sci Sports Exerc. 2009; 41(11): 2033.
(80) Robling AG. Is Bone's Response to Mechanical Signals Dominated by Muscle Forces? Med Sci Sports Exerc. 2009; 41(11): 2044.
(81) Judex S, Carlson KJ. Is Bone's Response to Mechanical Signals Dominated by Gravitational Loading? Med Sci Sports Exerc. 2009; 41(11): 2037.
(82) Kohrt WM, Barry DW, Schwartz RS. Muscle Forces or Gravity: What Predominates Mechanical Loading on Bone? Med Sci Sports Exerc. 2009; 41(11): 2050.
(83) Rubin CT, Lanyon LE. Regulation of Bone Mass by Mechanical Strain Magnitude. Calcif Tissue Int. 1985; 37(4): 411.
(84) Lanyon LE, Rubin CT. Static Vs Dynamic Loads as an Influence on Bone Remodelling. J Biomech. 1984; 17(12): 897.
(85) Rubin CT, Lanyon LE. Regulation of Bone Formation by Applied Dynamic Loads. J Bone Joint Surg Am. 1984; 66(3): 397.
(86) Burr DB, Robling AG, Turner CH. Effects of Biomechanical Stress on Bones in Animals. Bone. 2002; 30(5): 781.

(87) Robling AG, Hinant FM, Burr DB, Turner CH. Shorter, More Frequent Mechanical Loading Sessions Enhance Bone Mass. Med Sci Sports Exerc. 2002; 34(2): 196.

(88) Khan K, McKay HA, Haapasalo H, Bennell KL, Forwood MR, Kannus P, et al. Does Childhood and Adolescence Provide a Unique Opportunity for Exercise to Strengthen the Skeleton? 2000; 3(2): 150.

(89) Nikander R, Sievanen H, Heinonen A, Daly RM, Uusi-Rasi K, Kannus P. Targeted Exercise against Osteoporosis: A Systematic Review and Meta-Analysis for Optimising Bone Strength Throughout Life. BMC Med. 2010; 8: 47.

(90) Kannus P, Haapasalo H, Sankelo M, Sievanen H, Pasanen M, Heinonen A, et al. Effect of Starting Age of Physical Activity on Bone Mass in the Dominant Arm of Tennis and Squash Players. Ann Intern Med. 1995; 123(1): 27.

(91) Kriemler S, Zahner L, Puder JJ, Braun-Fahrlander C, Schindler C, Farpour-Lambert NJ, et al. Weight-Bearing Bones Are More Sensitive to Physical Exercise in Boys Than in Girls During Pre- and Early Puberty: A Cross-Sectional Study. Osteoporos Int. 2008; 19(12): 1749.

(92) Iuliano-Burns S, Stone J, Hopper JL, Seeman E. Diet and Exercise During Growth Have Site-Specific Skeletal Effects: A Co-Twin Control Study. Osteoporos Int. 2005; 16(10): 1225.

(93) Baxter-Jones AD, Kontulainen SA, Faulkner RA, Bailey DA. A Longitudinal Study of the Relationship of Physical Activity to Bone Mineral Accrual from Adolescence to Young Adulthood. Bone. 2008; 43(6): 1101.

(94) Kemper HC, Twisk JW, van Mechelen W, Post GB, Roos JC, Lips P. A Fifteen-Year Longitudinal Study in Young Adults on the Relation of Physical Activity and Fitness with the Development of the Bone Mass: The Amsterdam Growth and Health Longitudinal Study. Bone. 2000; 27(6): 847.

(95) van Mechelen W, Twisk JW, Kemper HC, Snel J, Post GB. Longitudinal Relationships between Lifestyle and Cardiovascular and Bone Health Status Indicators in Males and Females between 13 and 27 Years of Age; a Review of Findings from the Amsterdam Growth and Health Longitudinal Study. Public Health Nutr. 1999; 2(3A): 419.

(96) Hughes JM, Novotny SA, Wetzsteon RJ, Petit MA. Lessons Learned from School-Based Skeletal Loading Intervention Trials: Putting Research into Practice. Med Sport Sci. 2007; 51: 137.

(97) Hind K, Burrows M. Weight-Bearing Exercise and Bone Mineral Accrual in Children and Adolescents: A Review of Controlled Trials. Bone. 2007; 40(1): 14.

(98) Macdonald HM, Ashe MC, McKay HA. The Link between Physical Activity and Bone Strength across the Lifespan. Int J Clin Rheumatol. 2009; 4(4): 437.

(99) Naylor PJ, Macdonald HM, Zebedee JA, Reed KE, McKay HA. Lessons Learned from Action Schools! Bc--an 'Active School' Model to Promote Physical Activity in Elementary Schools. J Sci Med Sport. 2006; 9(5): 413.

(100) McKay HA, MacLean L, Petit M, MacKelvie-O'Brien K, Janssen P, Beck T, et al. "Bounce at the Bell": A Novel Program of Short Bouts of Exercise Improves Proximal Femur Bone Mass in Early Pubertal Children. Br J Sports Med. 2005; 39(8): 521.

(101) Macdonald HM, Kontulainen SA, Khan KM, McKay HA. Is a School-Based Physical Activity Intervention Effective for Increasing Tibial Bone Strength in Boys and Girls? J Bone Miner Res. 2007; 22(3): 434.

(102) Macdonald HM, Cooper DM, McKay HA. Anterior-Posterior Bending Strength at the Tibial Shaft Increases with Physical Activity in Boys: Evidence for Non-Uniform Geometric Adaptation. Osteoporos Int. 2009; 20(1): 61.

(103) Fuchs RK, Bauer JJ, Snow CM. Jumping Improves Hip and Lumbar Spine Bone Mass in Prepubescent Children: A Randomized Controlled Trial. J Bone Miner Res. 2001; 16(1): 148.

(104) Hasselstrom HA, Karlsson MK, Hansen SE, Gronfeldt V, Froberg K, Andersen LB. A 3-Year Physical Activity Intervention Program Increases the Gain in Bone Mineral and Bone Width in Prepubertal Girls but Not Boys: The Prospective Copenhagen School Child Interventions Study (Coscis). Calcif Tissue Int. 2008; 83(4): 243.

(105) Linden C, Ahlborg HG, Besjakov J, Gardsell P, Karlsson MK. A School Curriculum-Based Exercise Program Increases Bone Mineral Accrual and Bone Size in Prepubertal Girls: Two-Year Data from the Pediatric Osteoporosis Prevention (Pop) Study. J Bone Miner Res. 2006; 21(6): 829.

(106) Alwis G, Linden C, Ahlborg HG, Dencker M, Gardsell P, Karlsson MK. A 2-Year School-Based Exercise Programme in Pre-Pubertal Boys Induces Skeletal Benefits in Lumbar Spine. Acta Paediatr. 2008; 97(11): 1564.

(107) Valdimarsson O, Linden C, Johnell O, Gardsell P, Karlsson MK. Daily Physical Education in the School Curriculum in Prepubertal Girls During 1 Year Is Followed by an Increase in Bone Mineral Accrual and Bone Width--Data from the Prospective Controlled Malmo Pediatric Osteoporosis Prevention Study. Calcif Tissue Int. 2006; 78(2): 65.

(108) Lofgren B, Detter F, Dencker M, Stenevi-Lundgren S, Nilsson JA, Karlsson MK. Influence of a 3-Year Exercise Intervention Program on Fracture Risk, Bone Mass, and Bone Size in Prepubertal Children. J Bone Miner Res. 2011; 26(8): 1740.

(109) Karlsson MK. Does Exercise During Growth Prevent Fractures in Later Life? Med Sport Sci. 2007; 51: 121.

(110) Karlsson MK, Nordqvist A, Karlsson C. Sustainability of Exercise-Induced Increases in Bone Density and Skeletal Structure. Food Nutr Res. 2008; 52(0).

(111) Warden SJ, Fuchs RK, Castillo AB, Nelson IR, Turner CH. Exercise When Young Provides Lifelong

Benefits to Bone Structure and Strength. J Bone Miner Res. 2007; 22(2): 251.
(112) Warden SJ, Fuchs RK. Exercise and Bone Health: Optimising Bone Structure During Growth Is Key, but All Is Not in Vain During Ageing. Br J Sports Med. 2009; 43(12): 885.
(113) Nordstrom A, Karlsson C, Nyquist F, Olsson T, Nordstrom P, Karlsson M. Bone Loss and Fracture Risk after Reduced Physical Activity. J Bone Miner Res. 2005; 20(2): 202.
(114) Hernandez CJ, Beaupre GS, Carter DR. A Theoretical Analysis of the Relative Influences of Peak Bmd, Age-Related Bone Loss and Menopause on the Development of Osteoporosis. Osteoporos Int. 2003; 14(10): 843.

CHAPTER 2

Study aims

STUDY AIMS

Summarizing the mentioned points above, the growing years provide an unique opportunity to lay a foundation for the prevention of chronic diseases. Primary prevention is of particular importance considering the trend of increased overweight prevalence and physical inactivity of today's children. School provides the optimal setting for an intervention since all children, irrespective of their ethical and socioeconomic background can be reached early in life. However, before the wide and expensive implementation of such a program, several open questions have to be addressed.

1. Even though if several school-based physical activity intervention studies have been conducted during the last years, there is still no clear consensus about effective strategies to increase physical activity in children. Summarizing the existing knowledge of school-based intervention studies aiming at increasing physical activity is a first step to do and on which an optimal intervention program is based.

Aim 1. To identify and summarize existing reviews of school-based physical activity interventions and to carry out a systematic review of recent intervention studies and prospectively verify predefined factors that may play a role for a positive outcome. (Chapter 4)

2. School based physical activity interventions can focus on many aspects and intervene on different levels. As our goal was to enhance quality and quantity of physical education related physical activity, it made sense to determine the activity level of children during physical education to determine the potential of change.

Aim 2. To assess physical activity during regular physical education in randomly selected primary school children and to determine to what degree physical education contributes to overall physical activity. (Chapter 5)

3. Based on the gained knowledge of existing school-based intervention studies, and due to the mentioned lack of well-designed trials aiming at reducing the cardiovascular risk in healthy and representative children and our literature-based hypothesis that previous interventions were too mild, short or run by unqualified personnel, we conducted a new randomized controlled trial to examine how a multi-component stringent physical activity intervention over one school year may influence individual and clustered cardiovascular risk factors including aerobic fitness.

Aim 3. To assess the effectiveness of a general school-based physical activity program (KISS) during one school-year on fitness, body fat, physical activity, quality of life and cardiovascular risk in young school children. (Chapter 6)

However, gained effects may only be important for public health if they persist after the cessation of a program. As several review articles indicated, there is a lack of knowledge concerning the long-term effects of existing intervention studies. Aiming to assess this issue, we conducted a follow-up measurement three years after cessation of the intervention program.

Aim 4. To explore whether this physical activity intervention program (KISS) is sufficient for these positive fitness and health outcomes to persist over three years. (Chapter 7)

4. While there is good evidence that tailored jumping intervention programs may improve bone health during youth, it remains unclear, whether a general school-based physical activity program may have the same impact on bone mass. Therefore, we analysed if our intervention program was likewise effective at increasing bone mass in children to optimize peak bone mass. We also tested, whether obtained effects persisted three years after cessation of the intervention program.

Aim 5. To determine whether a general physical activity intervention program aiming at improving multiple health outcomes (KISS) increases bone mineral content and bone mineral density in children. (Chapter 8)

Aim 6. To investigate whether the beneficial intervention effects on bone health are maintained three years after the program had ceased. (Chapter 9)

CHAPTER 3

Kinder- und Jugendsportstudie (KISS)

KINDER- UND JUGENDSPORTSTUDIE (KISS)

The design of our school-based intervention study "Kinder- und Jugendsportstudie", shortened "KISS study" has been published elsewhere(1). Nevertheless, for a deeper understanding of this dissertation, an overview of the study design and the intervention program is given in the following paragraphs.

SWISS BACKGROUND

As in many Western countries, Switzerland fights against the increasing sedentary behavior of the population. Newest data showed that currently the prevalence for overweight and obesity among children in Switzerland aged 6 to 13 years is 16.7% and 13.1% for boys and girls, respectively(2). Nevertheless, political discussions about a reduction of the amount of physical education in the school curriculum are taking place since several years. Up to date, no or only scarce data exist about the physical health levels of Swiss school children(3, 4). The Swiss Federal Office of Sports (FOSPO) and in a second step the Swiss National Science Foundation (SNSF) therefore decided to support a study aiming at assessing the current level of physical activity, fitness and health of elementary school children in Switzerland, and in addition, test whether a school-based physical activity intervention program over the period of one academic year was successful at increasing physical activity and physical health of our children, including a follow-up of three years later.

SELECTION OF THE STUDY POPULATION

The KISS study has the design of a cluster-randomized controlled trial.

The study took place in the cantons Aargau and Baselland comprising about 10% of the Swiss population. To ensure the representativeness of the Swiss population, our inclusion criteria for participating schools were a prevalence of migrant children of 10 to 30%, an equal distribution of rural and urban localization, and for practical reasons the presence of at least one first and one fifth grade class. The recruitment took place in autumn 2004. Of the 919 elementary schools within these two cantons, 95 schools fulfilled the mentioned criteria and were willing to participate. Out of these schools, 15 schools were randomly selected and randomized into an intervention arm (9 schools from 6 different communities) and a control arm (6 schools from 3 different communities). Schools from the intervention and control arm were located in different villages or towns. Thus, children and parents of the control arm did not know about the existence of the intervention.

Since the intervention program itself was established as part of the school curriculum, it was mandatory for all children in the intervention group. However, children and their parents have to give their informed consent for all measurements. The study was approved by the ethic committees of the involved universities and the cantonal ethical committees.

INTERVENTION PROGRAM

The normal Swiss school curriculum schedules three physical education lessons per week with a duration of 45 min each. In primary school, the lessons are taught by the classroom teacher. During the intervention period, children of the control arm obtained these three physical education lessons per week.

The intervention program was delivered over a whole school year of nine months. It took place from August 2005 until June 2006. It was targeted at both the cluster and the individual level and was based on a socio-ecological conceptual model focusing on increasing daily physical activity(5). Additionally to the three compulsory physical education lessons per week taught by the classroom teachers, children of the intervention arm received the following program components:

Daily physical education lesson

Two additional physical education lessons per week of 45 min each were added to the curriculum, leading to a daily physical education lesson. The additional lessons were taught by a physical education expert teacher. As the classroom teachers took part in these lessons, the teachers got a continuous teaching education regarding their own physical education teaching habits. The two additional physical education lessons were compensated by reducing the number of academic lessons per week, thus children in the intervention group had the same amount of school lessons per week as the control group. Thereby, classroom teachers of the intervention classes could week by week chose which lessons to compensate. Every of the five weekly lessons followed a specified curriculum defined by the study organizers. With this, content, intensities and progression of the lessons could be regulated and all the intervention classes received the same program. The program was grade-adjusted and included both, coordinative tasks (i.e. balancing) and health related fitness task (i.e. endurance training, strength training). Since bone health was one of our study outcomes, each lesson included at least 10 minutes of jumping activities like hopping, jumping up and down stairs, rope skipping etc.

Short activity breaks during academic lessons

Classroom teachers were told to introduce several every day short activity breaks of 2-5 min during the academic lessons. Each intervention class received a dartboard (see Figure 3.1A) with five different task topics (“stimulating the cardiovascular system”, “strengthening muscles”, “improving agility”, “maintaining flexibility”, and “building stronger bones”). Children could throw the dart and depending on which topic was hit, a respective exercise was chosen from an exercise card set.

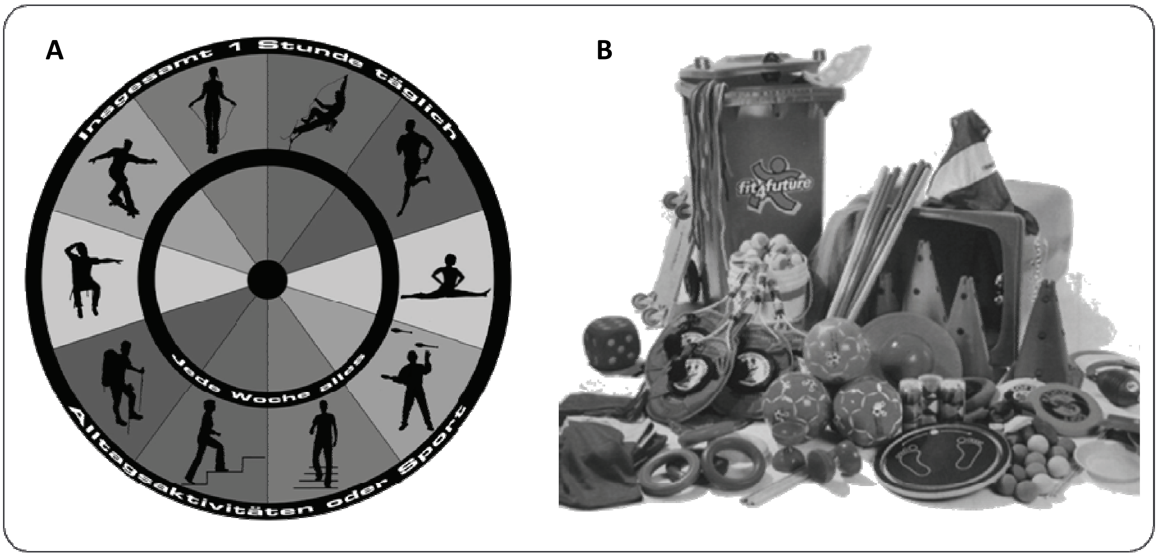

Figure 3.1 (A) Dartboard for short activity breaks during academic lessons (Health Promotion Switzerland; www.gesundheitsfoerderung.ch) and (B) recess playing material (Cleven-Stiftung; www.fit-4-future.ch)

Physical activity homework

The children received daily physical activity homework which they could do with their family members. The homework of about 10 minutes duration was prepared by the physical education experts and included motor skills, strength exercises, jumping activities or coordinative tasks (i.e. brushing their teeth while standing on one leg etc.).

Recess playing material

In the second part of the intervention, all intervention schools were equipped with recess playing material which children could use during their recess time (Figure 3.1B).

Information flyers for families

Families were encouraged to develop a healthy lifestyle by the distribution of flyers containing basic information about physically activity, healthy nutrition and reduced media consumption.

REFERENCES

(1) Zahner L, Puder JJ, Roth R, Schmid M, Guldimann R, Puhse U, et al. A School-Based Physical Activity Program to Improve Health and Fitness in Children Aged 6-13 Years ("Kinder-Sportstudie Kiss"): Study Design of a Randomized Controlled Trial [Isrctn15360785]. BMC Public Health. 2006; 6: 147.

(2) Aeberli I, Ammann RS, Knabenhans M, Molinari L, Zimmermann MB. Decrease in the Prevalence of Paediatric Adiposity in Switzerland from 2002 to 2007. Public Health Nutr. 2010; 13(6): 806.

(3) Delgrande Jordan M, Annaheim B. Habitudes Alimentaires, Activité Physique Et Statut Pondéral Chez Les Élàves De 11 À 15 Ans En Suisse. Situation En 2006 Et Évolution Récente - Résultats De L'énquête Internationale Health Behaviour in School-Aged Children (Hbsc). Lausanne: Institut suisse de prévention de l'alcoolisme et autres toxicomanies (ISPA); 2009.

(4) Michaud PA, Narring F, Cauderay M, Cavadini C. Sports Activity, Physical Activity and Fitness of 9- to 19-Year-Old Teenagers in the Canton of Vaud (Switzerland). Schweiz Med Wochenschr. 1999; 129(18): 691.

(5) Egger G, Swinburn B. An "Ecological" Approach to the Obesity Pandemic. Br Med J. 1997; 315(7106): 477.

CHAPTER 4

Effect of School-Based Interventions on Physical Activity and Fitness in Children and Adolescents: A Review of Reviews and Systematic Update

Susi Kriemler
Ursina Meyer
Eva Martin
Esther M. van Sluijs
Lars B. Andersen
Brian Martin

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EFFECT OF SCHOOL-BASED INTERVENTIONS ON PHYSICAL ACTIVITY AND FITNESS IN CHILDREN AND ADOLESCENTS: A REVIEW OF REVIEWS AND SYSTEMATIC UPDATE

ABSTRACT

School-based interventions are thought to be the most universally applicable and effective way to counteract low physical activity and fitness although there is controversy about the optimal strategy to intervene. The objective of this review was to summarize recent reviews that aimed to increase physical activity or fitness in youth and carry out a systematic review of new intervention studies. Relevant systematic reviews and original controlled and randomized controlled school-based trials with a physical activity or fitness outcome measure, a duration of ≥12 weeks, a sufficient quality and involvement of a healthy population aged 6-18 years that were published from 2007-2010 were included. In these reviews, 47-65% of trials were found to be effective. The effect was mostly seen in school-related physical activity while effects outside school were often not observed or assessed. The school-based application of multi-component intervention strategies was the most consistent, promising strategy, while controversy existed regarding the effectiveness of family involvement, focus on healthy populations at increased risk or duration and intensity of the intervention. All 20 trials in the review update showed a positive effect on in-school, out-of-school or overall physical activity, and 6 of 11 studies showed an increase in fitness. Taking into consideration both assessment quality and public health relevance, multi-component approaches in children including family components showed the highest level of evidence for increasing overall physical activity. This review confirms the public health potential of high quality, school-based physical activity interventions for increasing physical activity and possibly fitness in healthy youth.

INTRODUCTION

Physical inactivity and low fitness in children and adolescents are raising health burdens worldwide. Physical inactivity in adults has been established as one of the leading established risk factors for mortality(1) and burden of disease(2). Moreover, high fitness has been shown to prolong life and even seems to be able to counterbalance adiposity-related mortality(1). The fact that these factors also track into adulthood(3) emphasizes the necessity to evaluate and find effective strategies for increasing physical activity and fitness in youth. School is the place where almost all of the children and adolescents spend most of their days and family-based interventions have been shown to be of limited effectiveness(4, 5). Therefore, a focus on the globally available school system seems justified.

As well-performed and relatively recent systematic reviews were available, we decided to summarize existing knowledge from these reviews and focus on the new literature of school-based interventions not included in the earlier reviews. We have used compatible search strategies and have not included articles published during the periods studied in the earlier reviews, but some studies may have been included in several reviews.

The objective of this review was therefore to: (1) summarize recent reviews of studies that aimed to increase physical activity or fitness in children and adolescents; (2) define, based on these reviews, potentially relevant factors for a positive outcome; (3) carry out a systematic review of new intervention studies and prospectively verify the predefined factors.

METHODS

The base of this review was the collection of recent systematic reviews published after 2006 that summarized the evidence on physical activity promotion in children and adolescents and to update these reviews by searching original controlled and randomized controlled school-based trials published afterwards. The reviews were analyzed in detail by one researcher (SK) and discussed with the coauthors.

Literature search and quality control

For our own systematic review, we used a combination of the search strategy used by others[5, 6] and applied it to Pubmed, Medline, Embase, Psycinfo, Sportdiscus and Embase using a time frame from January 2007 to December 2010 (online supplementary Table 1). Inclusion criteria were: (1) controlled trials (CTs) or randomized controlled trials (RCTs) of interventions that aimed to increase physical activity or fitness, (2) target populations including school-aged children from 6 to 18 years of age (corresponding to mandatory school age), (3) physical activity or fitness measured as an outcome at baseline and at least one follow-up, (4) a duration of the intervention of at least 3 months, (5) intervention delivered at school, (6) control group not receiving a physical activity intervention and (7) statistical analyses of the physical activity/fitness outcome reported. Studies in children with a specific disease or studies applying structured exercise programs for obese children were excluded. Likewise, we did not include trials with the main goal of decreasing inactivity.

Two reviewers (SK, UM) each checked half of the titles and abstracts obtained from the searches. After exclusion of non-relevant studies, the full text of each remaining paper was read by two researchers (UM, SK or EM) who independently scored them. The methodological quality of the studies was then assessed using a predefined previously used quality assessment tool focusing mainly on internal validity[5] (online supplementary Table 3). Any disagreement was solved by discussion and studies with a weak methodology, that is, with a score below 5 of 10, were excluded.

Data extraction and evaluation

An overview of the studies included was established. Thereafter, a checklist with the relevant trial characteristics was constructed to allow a systematic data extraction. These factors included the age group (children vs adolescents), duration of the trials (interventions of 1 year or less vs longer trials), focus of the trials (solely on the school setting vs including also family or community components), implementation by classroom teachers or physical education specialists, mandatory or voluntary nature of the intervention and method of outcome assessment (accelerometers, pedometers or observation vs questionnaires; VO_2max test vs field tests). Children were defined as the age group up to 12 years, while adolescents were 13 years old or older. A program was defined mandatory if the intervention was an integral part of the school curriculum in which neither teachers nor children had the free choice of participation or withdrawal, and if there was a report of compliance or the intervention was monitored. This rating was carried out by two independent researchers prior to the systematic reporting of study results. In case of disagreement consensus was reached by discussion.

RESULTS

Summary and synthesis of recent reviews with focus on the school setting

Table 4.1 provides an overview of the four most recent and comprehensive systematic reviews covering physical activity promotion in schools(4-8). The reviews included CTs or (cluster-)RCTs with the goal of physical activity promotion in youth reporting a baseline and at least one follow-up measure of physical activity and/or fitness. Between 75%(4) and 100%(6) of the studies included focused on the school system. While the upper range of age included was generally 18-19 years, the lower range of age varied from no limit(5), to 4 years(4), 6 years(6) or 10 years(7). A description of the reviews and their conclusions is provided below.

Dobbins et al.(4) reviewed the available evidence of school-based physical activity promotion including trials up to June 2007. After a rigorous quality control of the potentially eligible trials based on Cochrane recommendations, they reported results of 26 studies. They reported positive impact on duration of physical activity (mostly for physical activity during school time) and on aerobic fitness measured by VO_2max, but there was no evidence that school-based trials also affected out-of-school physical activity positively. Although the authors were positive about the beneficial effects in general, this evidence was mostly based on self-reports. The authors discussed several limitations of included studies such as the low number of trials reporting out-of-school physical activity (n=7) despite the fact that the primary goal of most trials was to promote overall physical activity, the lack of long-term follow-up, and the measurement of physical activity mostly by self-report, which may have attenuated the results due to the inability of accurately reporting physical activity by children[9]. They further remarked that the most notable difference regarding effects on out-of-school physical activity was the use of physical education specialists to deliver the intervention. For physical activity in school, successful trials tended to intervene for a longer period and applied multi-component approaches. All these studies were conducted in children.

De Meester et al.[7] included trials in European teenagers that were published from 1995 to May 2008 and identified 20 relevant studies. They found that school-based interventions lead to short-term improvements in physical activity levels, but effects were limited to school-related physical activity with no conclusive transfer to out-of-school physical activity. In a second article integrating the analyses of effect sizes[8] they concluded, in contrast to the original review, that a multi-component approach including environmental components and a focus on physical activity only rather than aiming to change several health behaviors was most effective. Physical activity improvements were reported to be of short duration, as in all three studies including longer term follow-up increases were not maintained. The authors also discussed the absence of school-based physical activity increases to out-of-school physical activity increases. Their original suggestion of an additional involvement of families was supported by three favorable trials combining the school and family setting. However, based on the effect size calculations it was later considered premature[8].

Salmon et al.[4] reviewed the literature from 1985 to June 2006 and summarized the findings of 76 studies, with 57 (75%) of them carried out in the school setting. Half of the studies were effective at increasing physical activity (not further specified). The authors observed that 16 (64%) of 25 studies using objective physical activity measures reported positive effects on physical activity compared with 25 (38%) of 66 studies using questionnaires. They felt that multi-component interventions focusing on physical education that implemented activity breaks or included family strategies were most successful among children, but the situation was inconclusive in adolescents. In many trials, overall physical activity was not measured, leaving the debate open whether successful increases in physical activity during school would be sustained during out-of-school or rather compensated by a respective decrease as suggested[10, 11] by others. Many of the studies included in this review were not considered in the review by Dobbins et al.[6] because of weaknesses in their methodology, although this was recognized.

Table 4.1 Overview of systematic reviews of school-based PA or lifestyle interventions to increase PA or fitness in children and adolescents

	Dobbins	De Meester /Crutzen	Salmon	van Sluijs	Current review
Time searched	To June 2007	From January 1995 to May 2008	From January 1985 to June 2006	To December 2006	From January 2007 to December 2010
Databases searched	Medline, Biosis, Cinahl, Embase, Sportdiscus, Psycinfo, Sociological abstracts, Central	Pubmed, Medline, Web of Science, Sport Discus, Cochrane library	Medline, Biosis, Cinahl, Embase, Sportdiscus, Psycinfo, PsycARTICLES, Cochrane, Central, ScienceDirect, Web of Knowledge, Social SciSearch, Ovid Databases	Medline, Embase, Sportdiscus, Psycinfo, Pubmed, Scopus	Medline, Embase, Sportdiscus, Psycinfo, Pubmed, Scopus
Inclusion criteria	Primarily school-based interventions that promote PA and/or fitness	All interventions that promote PA among European teenagers	All interventions that promote PA	All interventions that promote PA	Primarily school-based interventions to promote PA and/or fitness
	CT or RCT with PA/fitness measured at baseline and postintervention				
Setting	School, school and/or family and/or community	School, family, community, primary care, internet	School, family, community, internet-based, primary care	School, family, community	School, school and family or community
Quality control	Cochrane recommendations, i.e. external validity, study design, confounders, blinding, reliability/validity of measurement tool, dropouts		No quality control	Based on predominantly internal validity, including baseline comparability, randomisation, unit of analyses, validated outcome measure, dropout, timing of measurement, follow-up measure, intention-to-treat analysis, blinding, confounding	
Exlusion critera	Low quality	If only fitness or PA during PE reported	Sample size (<n=16), if only fitness measured	None	Low quality, duration <3 months
Selected studies	n=26	n=20	n=76	n=57	n=20
In children/in adolescents/in both	22/4/0	0/22/0	42/25/9	33/24/0	15/4/1
In school setting	All (100%)	15/20 (75%)	57/76 (75%)	47/57 (82%)	All (100%)
Age (years)	6-18	10-19	4-19	≤18	6-18
Countries (USA+Canada/Europe/Other)	16/8/2	0/20/0	59/14/3	37/17/3	6/12/3
Overall results (with special focus on studies including the school system)	Positive impact on duration of PA in school (5/7 studies effective) and fitness (3/5 studies significant). No effect on LTPA outside school (3/7 studies significant). Only 3/26 studies with PA outcome included adolescents. PA mostly assessed by questionnaires, transfer from PA in school to LTPA or overall PA not assessed. Lack of long-term effects.	2/3 studies showed positive effects on short-term improvements in PA, but in 3/20 studies with follow-up PA improvements not sustained. PA improvements mostly during school with no conclusive transfer to LTPA.	Interventions more effective in the school than in other settings. Most studies did not assess overall PA. Studies that assessed PA objectively more effective than when PA assessed by questionnaires.	In half of the studies significant effect of the interventions on PA, about half children and adolescent studies. Interventions in adolescents more effective than in children. Target on migrants, those with low SES or girls only not effective. Purely educational interventions not effective	All studies showed a positive effect on one aspect of PA with 9/10 studies also documenting a positive effect on overall PA. 2/3 of studies showed increased fitness. The majority of studies measured LTPA and/or overall PA, 60% by objective means. Only 3 follow-ups, but all showing maintained effects in at least one PA domain.
Intervention success factors	Involvement of specialists (for LTPA) and longer duration of the intervention (for PA in school) associated with positive intervention effects.	Multicomponent programmes and those focusing only on PA rather than on multiple health behaviors, more effective. Family involvement inconclusive.	In children: effective studies included a focus on PE, activity breaks or involvement of the family and were multicomponent. In adolescents: unclear. Interventions only focusing on curriculum change much less effective than multicomponent interventions.	In children: no conclusion what type of intervention works best. In adolescents: multicomponent interventions and those involving families or community most effective.	In children: multicomponent interventions with family involvement most effective. In adolescents: inconclusive.
Significant effect on PA	8/14 (57%)	13/20 (65%)	38/76 (50%)	27/57 (42%)	16/16(100%)
Significant effect on fitness	3/5 (60%)	NA	NA	NA	6/11 (55%)
Significant effect on motor skills	NA	NA	NA	NA	4/6 (67%)

CT, controlled trial; LTPA, leisure time physical activity (PA outside school); NA, not applicable; PA, physical activity; PE, physical education; RCT, randomized controlled trial; SES, socioeconomic status.

Van Sluijs et al.[5] summarized all interventions with a physical activity promotion in youth up to December 2006. Fifty-seven studies were identified, with 47 involving the school system and about half of them of high quality. As in the other reviews presented above, a meta-analysis was not performed, because of the methodological heterogeneity of the studies. Although all studies that fulfilled the inclusion criteria were included, the level of evidence was drawn on the basis of consistency of results of studies with the highest available level of quality. Strong evidence was found for the effectiveness of multi-component interventions and for trials including both school and family or community components in adolescents, while there was no conclusive finding for the best strategy in children. Interventions seemed to be more effective in adolescents than in children. Based on their findings, the authors questioned the usefulness of interventions targeting ethnic minority populations or girls only, or approaches using isolated educational approaches. They also mentioned important limitations of many studies caused by the absent description of attendance, of implementation or of quality assurance in the interventions. The total lack of cross-cultural evaluation of the studies also made it impossible to generalize findings from different parts of the world.

In summary, the existing reviews of trials promoting physical activity in schools agreed upon their positive impact but have not supplied a clear picture of effective strategies to increase physical activity and/or fitness in youth. Their conclusions concerning the effects of specific intervention types in different age groups varied. Methodological limitations in existing studies were cited including the lack of valid physical activity measures, lack of data on overall physical activity and compliance, and the lack of studies with long-term follow-up or clear implementation strategies. All reviews requested more trials of adequate quality should be performed.

New literature since January 2007

Figure 4.1 presents a flowchart of the literature search. We identified 20 relevant trials (11 RCTs and 9 CTs) (online supplementary Table 2)[12-33] of sufficient quality (see online supplementary Table 3 for the rating system and the results of the methodological quality assessment) published between January 2007 and December 2010. Sixteen of 20 trials reported effects on a physical activity outcome, 11 of 20 reported on a fitness-related outcome and 6 of 20 also assessed motor skills. A list of excluded studies, based on full text reviews, is provided in online supplementary Table 4.

Three trials were performed in the USA, two in Canada, 12 in Europe, and one each in Australia, Brazil and Iran. The study size at baseline ranged from 132 to 2848 and the duration of the intervention from 6 months to 4 years, including seven trials with a duration of more than a year[12, 13, 16, 20, 28, 29, 32]. Only three trials reported follow-ups of 6-12 months after the end of the intervention[17, 24, 25]. Fourteen trials included children until 12 years of age, four studies were done in adolescents, and two trials included both age ranges. Most studies focused on a general population of school children, two studies only included girls[27, 30] and three focused on children from low socioeconomic backgrounds[22, 24, 25]. About half of the programs were mandatory rather than voluntary, also half of them were multi-component and 60% included family or community components. The intervention was applied by physical education experts in five studies, while in nine studies classroom teachers were responsible for the implementation, and in three studies a combination was used. Among the 16 studies with a physical activity outcome, 6 trials solely used questionnaires to assess physical activity[15, 18, 22, 26, 28, 30] and 10 used accelerometers or pedometers in the whole sample[14, 17, 19, 23-25] or a subsample[13, 19, 21, 32], including 6 that used a combination of physical activity assessments. Common methodological limitations of the included studies were missing information on the use of intention-to-treat analyses, on blinding procedures or on randomization procedures and compliance.

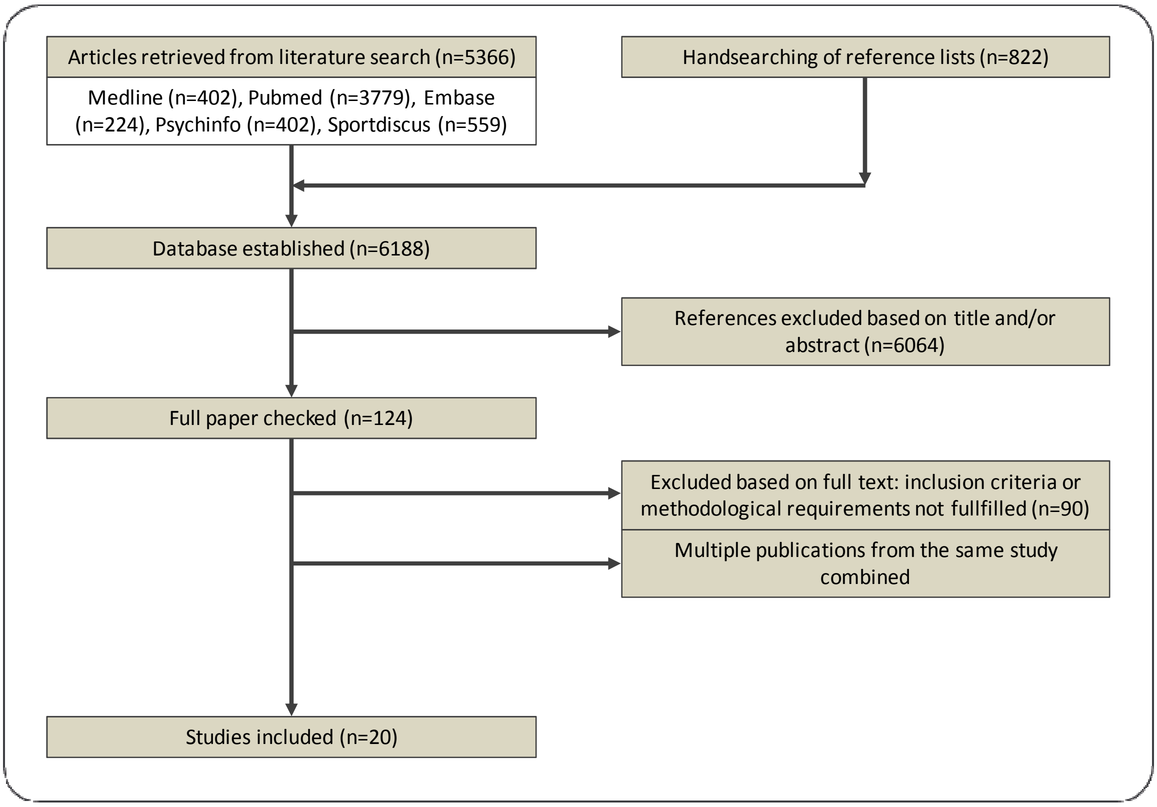

Figure 4.2 Flowchart of study selection.

Content wise, each single study was different and none of the program used the same content of interventional parts. Overall, four programs focused solely on education, four applied only curricular changes, one only changed the environment while the remaining trials used any combination of approaches with educational, curricular or environmental adaptations. About half of the programs complemented physical education lessons and/or added physical activity breaks, supported active play during recess, lunchtime or after school. This included, for example, adding additional physical education lessons, provision of equipment, more time for breaks, physical activity homework or special events during weekends. In addition, most programs added some sort of education as extra lessons during school or as integrated part of the usual curriculum. Two-thirds of all trials integrated family components ranging from simple written advice to audiovisual education or active participation in workshops with or without the children or adolescents. Main results are described in Table 4.2.

Effect on physical activity

The overall picture shows that every single study with a physical activity outcome (n=16) reported a significant intervention effect on at least one domain of physical activity, in-school, out-of-school or overall. We defined a hierarchy of physical activity findings including assessment quality (i.e. objective vs subjective means of physical activity measurement) and public health relevance (i.e. overall vs in-school vs out-of-school physical activity) by using one key physical activity measure per study that provided the strongest evidence of an intervention effect. Five studies were effective at increasing total physical activity assessed by accelerometers or pedometers(14, 17, 19, 23, 25), but two of them showed significant effects only in a subgroup(17, 23). By the use of questionnaires, total physical activity was increased in four studies(16, 18, 27, 30) (one in a subgroup(16)) while one did not show effects(21). In-school physical activity was increased in two studies(24, 31), both using objective means of assessing physical activity. Out-of-school physical activity was only assessed by subjective means, but all these four studies(13, 15, 22, 28) showed significant positive effects on physical activity in favor of the intervention. Among the three studies documenting a longer follow-up (6-12 months), all reported maintained effects in at least one measure of physical activity(17, 25, 34). Two RCTs with an intervention duration of one school year attained the highest hierarchy level of evidence with significant increases of objectively measured overall physical activity in the whole study population of children. One applied daily physical education lessons with additional physical activity breaks and physical activity homework(14), the other focused on providing weekly sessions of behavioral modification (regarding physical activity and sedentary behavior), improvement of fundamental motor skills or a combination of both(25). Both RCTs were integrated as part of the school curriculum, used physical education specialists and included family support.

Effect on aerobic fitness and motor skills

Aerobic fitness was assessed in 11 studies, of which 3 used spiroergometry (VO_2max)(27, 33, 35) and the remaining used field tests such as the shuttle run or a 6-minute run. Six studies(12, 14, 23, 27, 29, 33) showed significant intervention effects, including all studies with VO_2max measurements. They all used physical education specialists to implement the weekly program, which generally consisted of five sessions of at least 45 minutes. Six studies also assessed motor skills in addition to fitness or physical activity(16, 20, 25, 29, 31, 33). Measurements differed considerably, ranging from observational ratings of the form and function of fundamental movement skills like forehead strike, lift and carry or leap[16] to different validated tests batteries such as the body coordination test (KTK)[20, 33] or the Eurofit test[29, 32]. Four of the trials[16, 20, 25, 29] showed significant positive intervention effects. Concomitant effects on fitness or physical activity were inconsistent and heterogeneous. No follow-up assessments for fitness or motor skills were reported.

Table 4.1 Overview of the studies included in the updated review, classified by effectiveness on physical activity, fitness and motor skills.

Study (first author and year of publication)	Oucome measure: outcome instrument	Results			
		Total PA	PA in school or LTPA	Fitness	Motor skills
Angelopoulos 2009	PA: quest		+ (LTPA)		
Boyles-Holmes 2010	PA: quest, FIT: field, MS: qual	++ (4th grade)		0	+
Gentile 2009	PA: ped, quest	0 (all),+ (girls)			
Gomes 2009	PA: quest	+			
Gorely 2009	PA: ped, acc^{ss}, FIT: field	+, (+ Acc^{ss})		0	
Graf 2008	FIT: field, MS: quant			0	+ (1 of 4 tests)
Haerens 2007	PA: quest , acc^{ss}	0, (+ Acc^{ss})	+ (PA in school), 0 (LTPA)		
Kriemler 2010	PA: acc, FIT: field	+	+ (PA in school)	+	
de Meij 2010	PA: quest, acc^{ss}, FIT: field	(0 Acc^{ss})	+ (Sports participation)	0	
Mc Neil 2008	PA: quest		+ (LTPA)		
Naylor 2008	PA: ped, quest^{ss}, FIT: field^{ss}	+ (boys)		+^{ss}	
Reseland 2009	FIT: VO_2max			+	
Ridgers 2007	PA: acc, hr		+ (Recess, lunch)		
Salmon 2008	PA: acc, MS: qual	+			0 (all), + (girls)
Schneider 2008	PA: quest, FIT: VO_2max	+	+ (LTPA)	+	
Simon 2008	PA: quest		+ (LTPA)		
Sollerhed 2008	FIT: field, MS: quant			+	+
Taymoori 2008	PA: quest	+			
Verstraete 2007	PA: quest, obs^{ss}, acc^{ss}, FIT: field, MS: quant	(+ Acc^{ss})	+ (LTPA), + (obs^{ss}), 0 (Acc^{ss})	0	0
Walther 2009	FIT: VO_2max, MS: quant			+	0
Summary	PA only (n=8)	+ (n=6)	+ (n=8)	+ (n=5)	+ (n=3)
		+^{ss} (n=1)		+^{ss} (n=1)	
	FIT only (n=4)	+^{sg} (n=3)			+^{sg} (n=1)
	Combined (n=8)	0 (n=2)	0 (n=1)	0 (n=5)	0 (n=2)
		0^{ss} (n=1)			
		NA (n=8)	NA (n=11)	NA (n=9)	NA (n=14)

^{ss}Subsample, random subset of individuals from within the whole population.
^{sg}Subgroup, group within the study population with a defined characteristic (ie, gender, grade).
+, significant positive effect of the intervention; +^{ss}, significant effect in a subsample; +^{sg}, significant effect in a subgroup; 0, no effect of the intervention; 0^{ss}, no effect in a subsample.
Acc, PA measured by accelerometers; field, fitness assessed by field test; FIT, fitness; hr, PA assessed by heart rate; LTPA, leisure time physical activity; MS, motor skills; NA, not applicable/not assessed; obs, PA assessed by observation; PA, physical activity; ped, PA measured by pedometers; qual, qualitative assessment of motor skills; quant, quantitative assessment of motor skills; quest, questionnaire based PA assessment; TPA, total physical activity; VO_2max, fitness assessed by measurement of maximal oxygen uptake.

DISCUSSION

The school setting has long been defined as the ideal setting for physical activity promotion interventions. As young people spend the majority of their waking hours in the school setting, it is possible to globally reach the population of interest without having to stigmatizise or discriminate and without being primarily dependent on families. Recent reviews generally showed that school-based physical activity promotion was effective at increasing physical activity during school, while the critical transfer to a parallel increase in out-of-school or overall physical activity was less clear. The reviews agreed that multi-component interventions combining educational, curricular and environmental elements seem to be more effective than isolated education(5) or curricular changes(4), but opinions differed on whether this was the case for children and adolescents. In some reviews, the focus on change of multiple health behaviors instead of focusing only on physical activity was considered as a stumbling block for success(6, 7). The involvement of families within school-based interventions was well supported by most(4-6), but not all reviews(7, 8). While van Sluijs et al.(5) stated that studies in adolescents tended to be more successful than in children possibly because of more potential for change and/or a higher quality of studies, the other reviews were unable to draw the same conclusion, possibly limited by small numbers of trials in the adolescent age range. In general, it was highlighted that many studies were of questionable methodology, that is, they assessed only school-related physical activity and used only questionnaires or permitted only conclusions on short-term follow-up. There was questionable generalizability because of the lack of trans-cultural studies.

The updated literature review identified 20 studies that fulfilled the inclusion and quality criteria and revealed a highly consistent picture with all included studies documenting significant effects on at least one measure of physical activity and 6 out of11 trials reporting a significant positive effect on fitness. These findings document stronger evidence than ever that school-based physical activity interventions are able to increase physical activity and possibly fitness in healthy children and adolescents. The intervention effects were consistently positive for physical activity in school, out-of-school physical activity and even more importantly in 9 out of10 studies for overall physical activity. In contrast to most previous reviews, only trials with adequate methodology, a pre-assessment and post-assessment of physical activity or fitness and a minimal duration of 3 months were included. The minimal duration was chosen to ascertain training effects(36) and at least some sustainability of behavioral change as suggested(6), thereby increasing the strength of evidence of these findings. Of note, the inclusion of four studies excluded only based on short duration(37-40) would not have changed the conclusions drawn here.

Publication bias in the sense of under-reporting of studies with negative effects might have influenced the overall picture, particularly given the high number of effective studies. However, given the considerable effort that goes into carrying out a proper outcome assessment, it can be assumed that researchers willing to make this effort will also strive to publish their findings even if they are negative. Therefore, one might consider not generalizing the conclusions of this review to low intensity and low effort physical activity promotion interventions in schools.

The fact that 20 trials were eligible over a 4-year period (compared to 26 trials over 50 years in the Cochrane review[6]) shows important progress in quality of the published studies. Seventy-five per cent of all trials assessing a physical activity outcome reported on overall physical activity; in 60% of all studies the physical activity outcome was measured by objective means. The predominance of positive intervention effects on physical activity was no longer limited to school-based physical activity, but extended to out-of-school and overall physical activity. From a public health perspective, this is a very important finding.

In the current compared to the previous reviews, the proportion of European studies was considerably higher. The methodological quality of the included studies has improved considerably, with more overall and objective assessments of physical activity and with more adequate statistical analyses (i.e, power analyses, cluster adjustment). When looking at the trials with the highest combined hierarchy level of quality and public health relevance (i.e, RCTs that assessed *overall* physical activity *objectively* and found significant effects in the *whole study population*), they included children, intervened over one school year by multi-component approaches including physical education, behavioral modification lessons or a combination. The programs were integrated into the regular school curriculum and taught by physical education experts, and tried to involve families using written information. Although one has to be cautious to draw conclusions based on two trials, a multi-component mandatory program with the involvement of specialists and supported by the families seems to be effective in increasing overall physical activity in children. Interestingly, similar conclusions have been drawn for lifestyle interventions in children to reduce obesity[41].

These findings confirm previous recommendations to use multi-component approaches in children to broaden the reach of the population of interest[4, 5], and to include families as important mediators for physical activity outside school[4] and for positive attitudes towards physical activity in general[42]. Whether the involvement of family components in school-based interventions for adolescents proves beneficial remains open for debate. While van Sluijs et al.[5] described strong evidence based on positive findings in two out of three high quality RCTs, the findings in the review by De Meester et al.[7] were inconclusive and effect sizes in the three effective studies were at most moderate[8]. It is possible that the influence of the family on health behavior becomes less important in debonding adolescents who are trying to become autonomous.

There was no difference in the effect of interventions on physical activity regardless of whether the study used objective or self-report measures of physical activity, which is in contrast to the findings of previous reviews[4, 5]. However, several studies used objective means of physical activity assessment only in a subpopulation[13, 19, 21, 31], which may have induced a selection bias, and some even reported discordant findings when objective and subjective means were both applied[21]. Nevertheless, there is no doubt that objective means of assessing physical activity in the whole study population should be the goal in the future[43]. Methodological limitations such as the absence of proper description of the randomization procedures to judge representativeness of the population, of documentation of compliance of those applying or receiving the intervention and, finally, of long-term follow-ups were still present.

Trials assessing aerobic fitness by VO_2max were consistently effective at increasing it, while only half of the trials using field tests showed positive effects. Additional factors differentiating effective from ineffective trials were a duration of the intervention of less than 1 year, a mandatory compared with a voluntary nature of the intervention, and an intervention in school only rather than extending it to the family or community. Importantly, all these trials used physical education specialists to implement the program, which consisted of daily sessions of at least 45 minutes. Studies without an effect on fitness were less intensive, less extensive and mostly voluntary in nature. This underlines the importance of an intervention of sufficient quantity and quality. The method of measuring aerobic fitness may also be an important consideration, since field tests may have methodological limitations in precision, motivation and standardization. The fact that shorter programs were more effective highlights the risk of losing the interest of teachers and pupils over time. The success of mandatory programs could be indirect evidence that compliance is one of most critical factors in school-based interventions to raise aerobic fitness as one of the most important health factor in youth[36].

In general, effects of the intervention on physical activity were stronger than the effects on fitness. This might be because the changes in physical activity were not sufficient to cause changes in fitness, the measurements were not of sufficient accuracy or there was simply over-reporting.

Motor skills were not defined as a main outcome in this review, but they were reported as additional finding in some trials. Four of six studies showed significant intervention effects on motor skills, but concomitant effects on fitness or physical activity were heterogeneous. Based on this review we cannot draw any conclusion on the relevance of focusing on motor skills to increase physical activity or fitness, although it may be plausible that children and adolescents with improved motor skills would have the precondition to increase their fitness or physical activity by their improved competence[44].

There is now good evidence that school-based interventions can increase physical activity and fitness in youth. Although this is a first step towards improving health and well-being in youth, we are still faced with the much bigger challenge of establishing sustainability of these interventions and their effects as well as transferring these programs into real world settings. The proof of sustainability of effects in these efficacy trials will probably never be done due to the ‘dispersion nature’ of schoolchildren. Some research groups have tried to perform long-term follow-ups but evidence remains brittle because of the tiny percentage of original study populations that could be reached[45-47]. Yet, effectiveness trials in larger populations and different settings may shed light on the capacity of large-scale and long-term health effects of physical activity promotion in youth as nicely shown in malaria prevention programs[48]. One program that may be an example in this direction is the Action Schools! BC initiative[49, 50], which was started in 2004 including 275 schools and 25 740 children and reaching 550 000 children 6 years later. This implementation was supported by the provincial government mandating 30 minutes of daily physical activity in schools. In order to find the best effectiveness for physical activity interventions in youth, research efforts should include studying mediation of the intervention effect[51, 52] and implementation issues[53, 54], which should enable us to successfully reach large populations. Further research also needs to consider the generalizability of the results as most of the studies included in the updated review originated from Europe. Now that we are more confident that school-based physical activity interventions have the potential to change young people's physical activity behavior, at least in the short term, we need to focus on programs that obtain the highest effect sizes[8], but also study the cost-effectiveness in real-world trials ideally with long-term follow-ups. Only then can we be more confident that physical activity changes in youth can be sustained and translated into better health in later life, as previously suggested[36, 47, 55-57].

CONCLUSION

This review shows strong evidence for the positive effect of school-based interventions on physical activity in children and adolescents. These conclusions are based on four systematic reviews published after 2006 of studies focusing on physical activity promotion in school and other settings and on a new systematic review of trials published between January 2007 and December 2010. Our review of the more recent publications is the first to show that physical activity promotion in the school setting leads to an increase in school-based physical activity, and is associated with an increase in out-of-school, and even more importantly, in overall physical activity. There is some evidence that school-based interventions can have positive effects on aerobic fitness, although this evidence is weak. Since efficacy of school-based physical activity promotion is globally evident, the time is ripe to look at long-term effects and to figure out effective implementation strategies.

REFERENCES

(1) Lee CD, Blair SN, Jackson AS. Cardiorespiratory Fitness, Body Composition, and All-Cause and Cardiovascular Disease Mortality in Men. Am J Clin Nutr. 1999; 69(3): 373.

(2) World Health Organization. Who. Global Health Risks. Mortality and Burden of Disease Attributable to Selected Major Risks. Geneva: World Health Organisation; 2009.

(3) Twisk JW, Kemper HC, van Mechelen W. Tracking of Activity and Fitness and the Relationship with Cardiovascular Disease Risk Factors. Med Sci Sports Exerc. 2000; 32(8): 1455.

(4) Salmon J, Booth ML, Phongsavan P, Murphy N, Timperio A. Promoting Physical Activity Participation among Children and Adolescents. Epidemiol Rev. 2007; 29: 144.

(5) van Sluijs EMF, McMinn AM, Griffin S. Effectiveness of Interventions to Promote Physical Activity in Children and Adolescents: Systematic Review of Controlled Trials. Br Med J. 2007; 335(7622): 703.

(6) Dobbins M, De Corby K, Robeson P, Husson H, Tirilis D. School-Based Physical Activity Programs for Promoting Physical Activity and Fitness in Children and Adolescents Aged 6-18. Cochrane Database Syst Rev. 2009; (1): Cd007651.

(7) De Meester F, van Lenthe FJ, Spittaels H, Lien N, De Bourdeaudhuij I. Interventions for Promoting Physical Activity among European Teenagers: A Systematic Review. Int J Behav Nutr Phys Act. 2009; 6.

(8) Crutzen R. Adding Effect Sizes to a Systematic Review on Interventions for Promoting Physical Activity among European Teenagers. Int J Behav Nutr Phys Act. 2010; 7.

(9) Sallis JF, Saelens BE. Assessment of Physical Activity by Self-Report: Status, Limitations, and Future Directions. Res Q Exerc Sport. 2000; 71(2 Suppl): S1.

(10) Mallam KM, Metcalf BS, Kirkby J, Voss LD, Wilkin TJ. Contribution of Timetabled Physical Education to Total Physical Activity in Primary School Children: Cross Sectional Study. Br Med J. 2003; 327(7415): 592.

(11) Donnelly JE, Jacobsen DJ, Whatley JE, Hill JO, Swift LL, Cherrington A, et al. Nutrition and Physical Activity Program to Attenuate Obesity and Promote Physical and Metabolic Fitness in Elementary School Children. Obes Res. 1996; 4(3): 229.

(12) Resaland GK, Andersen LB, Mamen A, Anderssen SA. Effects of a 2-Year School-Based Daily Physical Activity Intervention on Cardiorespiratory Fitness: The Sogndal School-Intervention Study. Scand J Med Sci Sports. 2011; 21(2): 302.

(13) de Meij JS, Chinapaw MJ, van Stralen MM, van der Wal MF, van Dieren L, van Mechelen W. Effectiveness of Jump-in, a Dutch Primary School-Based Community Intervention Aimed at the Promotion of Physical Activity. Br J Sports Med. 2011; 45(13): 1052.

(14) Kriemler S, Zahner L, Schindler C, Meyer U, Hartmann T, Hebestreit H, et al. Effect of School Based Physical Activity Programme (Kiss) on Fitness and Adiposity in Primary Schoolchildren: Cluster Randomised Controlled Trial. Br Med J. 2010; 340(feb23 1): c785.

(15) Angelopoulos PD, Milionis HJ, Grammatikaki E, Moschonis G, Manios Y. Changes in Bmi and Blood Pressure after a School Based Intervention: The Children Study. Eur J Public Health. 2009; 19(3): 319.

(16) Boyle-Holmes T, Grost L, Russell L, Laris B, Robin L, Haller E, et al. Promoting Elementary Physical Education: Results of a School-Based Evaluation Study. Health Educ Behav. 2010; 37(3): 377.

(17) Gentile DA, Welk G, Eisenmann JC, Reimer RA, Walsh DA, Russell DW, et al. Evaluation of a Multiple Ecological Level Child Obesity Prevention Program: Switch What You Do, View, and Chew. BMC Med. 2009; 7: 49.

(18) Gomes de Barros MV, Nahas MV, Hallal PC, Cazuzade Farias J, Jr., Florindo AA, Honda de Barros SS. Effectiveness of a School-Based Intervention on Physical Activity for High School Students in Brazil: The Saude Na Boa Project. J Phys Act Health. 2009; 6(2): 163.

(19) Gorely T, Nevill ME, Morris JG, Stensel DJ, Nevill A. Effect of a School-Based Intervention to Promote Healthy Lifestyles in 7-11 Year Old Children. Int J Behav Nutr Phys Act. 2009; 6.

(20) Graf C, Koch B, Falkowski G, Jouck S, Christ H, Staudenmaier K, et al. School-Based Prevention: Effects on Obesity and Physical Performance after 4 Years. J Sports Sci. 2008; 26(10): 987.

(21) Haerens L, De Bourdeaudhuij I, Maes L, Cardon G, Deforche B. School-Based Randomized Controlled Trial of a Physical Activity Intervention among Adolescents. J Adolesc Health. 2007; 40(3): 258.

(22) McNeil DA, Wilson BN, Siever JE, Ronca M, Mah JK. Connecting Children to Recreational Activities: Results of a Cluster Randomized Trial. Am J Health Promot. 2009; 23(6): 376.

(23) Naylor PJ, Macdonald HM, Warburton DE, Reed KE, McKay HA. An Active School Model to Promote Physical Activity in Elementary Schools: Action Schools! Bc. Br J Sports Med. 2008; 42(5): 338.

(24) Ridgers ND, Stratton G, Fairclough SJ, Twisk JW. Long-Term Effects of a Playground Markings and Physical Structures on Children's Recess Physical Activity Levels. Prev Med. 2007; 44(5): 393.

(25) Salmon J, Ball K, Hume C, Booth M, Crawford D. Outcomes of a Group-Randomized Trial to Prevent Excess Weight Gain, Reduce Screen Behaviours and Promote Physical Activity in 10-Year-Old Children: Switch-Play. Int J Obes. 2008; 32(4): 601.

(26) Schneider M, Dunton GF, Cooper DM. Physical Activity and Physical Self-Concept among

Sedentary Adolescent Females: An Intervention Study. Psychol Sport Exerc. 2008; 9(1): 1.
(27) Schneider M, Dunton GF, Bassin S, Graham DJ, Eliakim AF, Cooper DM. Impact of a School-Based Physical Activity Intervention on Fitness and Bone in Adolescent Females. J Phys Act Health. 2007; 4(1): 17.
(28) Simon C, Schweitzer B, Oujaa M, Wagner A, Arveiler D, Triby E, et al. Successful Overweight Prevention in Adolescents by Increasing Physical Activity: A 4-Year Randomized Controlled Intervention. Int J Obes. 2008; 32(10): 1489.
(29) Sollerhed AC, Ejlertsson G. Physical Benefits of Expanded Physical Education in Primary School: Findings from a 3-Year Intervention Study in Sweden. Scand J Med Sci Sports. 2008; 18(1): 102.
(30) Taymoori P, Niknami S, Berry T, Lubans D, Ghofranipour F, Kazemnejad A. A School-Based Randomized Controlled Trial to Improve Physical Activity among Iranian High School Girls. Int J Behav Nutr Phys Act. 2008; 5.
(31) Verstraete SJM, Cardon GM, De Clercq DLR, De Bourdeaudhuij IMM. A Comprehensive Physical Activity Promotion Programme at Elementary School: The Effects on Physical Activity, Physical Fitness and Psychosocial Correlates of Physical Activity. Public Health Nutr. 2007; 10(5): 477.
(32) Verstraete SJM, Cardon GM, De Clercq DLR, De Bourdeaudhuij IMM. Effectiveness of a Two-Year Health-Related Physical Education Intervention in Elementary Schools. J Teach Phys Educ. 2007; 26(1): 20.
(33) Walther C, Gaede L, Adams V, Gelbrich G, Leichtle A, Erbs S, et al. Effect of Increased Exercise in School Children on Physical Fitness and Endothelial Progenitor Cells a Prospective Randomized Trial. Circulation. 2009; 120(22): 2251.
(34) Ridgers ND, Fairclough SJ, Stratton G. Twelve-Month Effects of a Playground Intervention on Children's Morning and Lunchtime Recess Physical Activity Levels. J Phys Act Health. 2010; 7(2): 167.
(35) Resaland GK, Mamen A, Anderssen SA, Andersen LB. Cardiorespiratory Fitness and Body Mass Index Values in 9-Year-Old Rural Norwegian Children. Acta Paediatr. 2009; 98(4): 687.
(36) Strong WB, Malina RM, Blimkie CJ, Daniels SR, Dishman RK, Gutin B, et al. Evidence Based Physical Activity for School-Age Youth. J Pediatr. 2005; 146(6): 732.
(37) Francis M, Nichols SS, Dalrymple N. The Effects of a School-Based Intervention Programme on Dietary Intakes and Physical Activity among Primary-School Children in Trinidad and Tobago. Public Health Nutr. 2010; 13(5): 738.
(38) Hill C, Abraham C, Wright DB. Can Theory-Based Messages in Combination with Cognitive Prompts Promote Exercise in Classroom Settings? Soc Sci Med. 2007; 65(5): 1049.
(39) Horne PJ, Hardman CA, Lowe CF, Rowlands AV. Increasing Children's Physical Activity: A Peer Modelling, Rewards and Pedometer-Based Intervention. Eur J Clin Nutr. 2009; 63(2): 191.
(40) McManus AM, Masters RS, Laukkanen RM, Yu CC, Sit CH, Ling FC. Using Heart-Rate Feedback to Increase Physical Activity in Children. Prev Med. 2008; 47(4): 402.
(41) Connelly JB, Duaso MJ, Butler G. A Systematic Review of Controlled Trials of Interventions to Prevent Childhood Obesity and Overweight: A Realistic Synthesis of the Evidence. Public Health. 2007; 121(7): 510.
(42) Heitzler CD, Martin SL, Duke J, Huhman M. Correlates of Physical Activity in a National Sample of Children Aged 9-13 Years. Prev Med. 2006; 42(4): 254.
(43) Corder K, Ekelund U, Steele RM, Wareham NJ, Brage S. Assessment of Physical Activity in Youth. J Appl Physiol. 2008; 105(3): 977.
(44) Lubans DR, Morgan PJ, Cliff DP, Barnett LM, Okely AD. Fundamental Movement Skills in Children and Adolescents: Review of Associated Health Benefits. Sports Med. 2010; 40(12): 1019.
(45) Kafatos I, Manios Y, Moschandreas J, Kafatos A. Health and Nutrition Education Program in Primary Schools of Crete: Changes in Blood Pressure over 10 Years. Eur J Clin Nutr. 2007; 61(7): 837.
(46) Klepp KI, Tell GS, Vellar OD. Ten-Year Follow-up of the Oslo Youth Study Smoking Prevention Program. Prev Med. 1993; 22(4): 453.
(47) Trudeau F, Laurencelle L, Tremblay J, Rajic M, Shephard RJ. Daily Primary School Physical Education: Effects on Physical Activity During Adult Life. Med Sci Sports Exerc. 1999; 31(1): 111.
(48) Magesa SM, Lengeler C, deSavigny D, Miller JE, Njau RJ, Kramer K, et al. Creating an "Enabling Environment" for Taking Insecticide Treated Nets to National Scale: The Tanzanian Experience. Malar J. 2005; 4: 34.
(49) Naylor PJ, McKay HA. Prevention in the First Place: Schools a Setting for Action on Physical Inactivity. Br J Sports Med. 2009; 43(1): 10.
(50) Reed KE, Warburton DE, Macdonald HM, Naylor PJ, McKay HA. Action Schools! Bc: A School-Based Physical Activity Intervention Designed to Decrease Cardiovascular Disease Risk Factors in Children. Prev Med. 2008; 46(6): 525.
(51) Haerens L, Cerin E, Maes L, Cardon G, Deforche B, De Bourdeaudhuij I. Explaining the Effect of a 1-Year Intervention Promoting Physical Activity in Middle Schools: A Mediation Analysis. Public Health Nutr. 2008; 11(5): 501.
(52) Lubans DR, Morgan PJ, Callister R, Collins CE, Plotnikoff RC. Exploring the Mechanisms of Physical Activity and Dietary Behavior Change in the Program X Intervention for Adolescents. J Adolesc Health. 2010; 47(1): 83.
(53) Naylor PJ, Scott J, Drummond J, Bridgewater L, McKay HA, Panagiotopoulos C. Implementing a Whole School Physical Activity and Healthy Eating Model in Rural and Remote First Nations Schools:

A Process Evaluation of Action Schools! Bc. Rural Remote Health. 2010; 10(2): 1296.
(54) De Meij JS, Chinapaw MJ, Kremers SP, Van der Wal MF, Jurg ME, Van Mechelen W. Promoting Physical Activity in Children: The Stepwise Development of the Primary School-Based Jump-in Intervention Applying the Re-Aim Evaluation Framework. Br J Sports Med. 2010; 44(12): 879.
(55) Perez CE. Children Who Become Active. Health Rep. 2003; 14 Suppl: 17.
(56) Li S, Zhao JH, Luan J, Ekelund U, Luben RN, Khaw KT, et al. Physical Activity Attenuates the Genetic Predisposition to Obesity in 20,000 Men and Women from Epic-Norfolk Prospective Population Study. PLoS Med. 2010; 7(8).
(57) Andersen LB, Harro M, Sardinha LB, Froberg K, Ekelund U, Brage S, et al. Physical Activity and Clustered Cardiovascular Risk in Children: A Cross-Sectional Study (the European Youth Heart Study). Lancet. 2006; 368(9532): 299.

CHAPTER 5

Contribution of physical education to overall physical activity

Ursina Meyer
Ralf Roth
Lukas Zahner
Markus Gerber
Jardena J. Puder
Helge Hebestreit
Susi Kriemler

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CONTRIBUTION OF PHYSICAL EDUCATION TO OVERALL PHYSICAL ACTIVITY

ABSTRACT

For many children, physical activity during physical education lessons provides an important opportunity for being physically active. Although physical activity during physical education has been shown to be low, little is known about the contribution of physical activity during physical education to overall physical activity. The aim was therefore to assess children's physical activity during physical education and to determine the contribution of physical education to overall physical activity with special focus on overweight children. Accelerometer measurements were done in 676 children (9.3±2.1 years) over 4-7 days in 59 randomly selected classes. Moderate-and-vigorous physical activity (MVPA; ≥2000 counts/min) during physical education ($MVPA_{PE}$), overall MVPA per day ($MVPA_{DAY}$), and a comparison of days with and without physical education were calculated by a regression model with gender, grade and weight status (normal vs. overweight) as fixed factors and class as a random factor. Children spent 32.8±15.1% of physical education time in MVPA. Weight status was not associated to $MVPA_{PE}$. $MVPA_{PE}$ accounted for 16.8±8.5% of $MVPA_{DAY}$, and 17.5±8.2% in overweight children. All children were more active on days with than on days without physical education (differences: 16.1±29.0 min of $MVPA_{DAY}$; $p \leq 0.001$; 13.7±28.0 min for overweight children). Although $MVPA_{PE}$ was low, physical education played a considerable role in providing physical activity and was not compensated by reducing extracurricular MVPA.

INTRODUCTION

There is no doubt about the importance of physical activity during childhood and its preventive effects on health[1, 2]. As children spend about half of their waking hours in school, the school setting plays an important role in providing and promoting physical activity[3, 4]. This role might even become more important from a public health perspective considering the growing evidence that physical activity has decreased over the last decades[5]. For an increasing number of children, in-school physical activity provides the main opportunity for being physically active[6] and this might even be more relevant for overweight children, who are generally less active than their normal weight counterparts[7]. Yet, a reduction of mandatory physical education lessons is discussed in several western countries because of the increased competition with other academic areas[5, 8, 9].

Extracurricular sport participation like sport club participation, after school programs or simply unorganized leisure-time physical activity have been shown to contribute at least 50% of overall physical activity in children and adolescents[10]. However, these are freely chosen activities that are often selected by the already active population and often do not reach those who need it most. The provision of a sufficient amount of physical activity during school may be one way to act effectively on a population level[3].

The goals of physical education are broad and reach from teaching of motor competencies to learning how to value physical activity for health, self-expression, and developing of personal and social competencies(11). Providing regular participation in physical activity is therefore only one goal of physical education, but may be the only opportunity to attain a minimum of physical activity for a considerable percentage of the inactive population. Nevertheless, physical activity levels during physical education have been shown to be relatively low. A systematic review(12) revealed that the percentage of time spent in moderate-and-vigorous physical activity (MVPA) was only about one third of total physical education time. To our knowledge, there is no study with a representative and randomly selected sample of children determining the contribution of physical education to overall physical activity. Previous studies focused selective samples(13, 14). However, given the relatively low amount of MVPA primary schoolchildren accumulate during a weekday(2), the contribution of physical education might still be substantial. Thus, even though physical activity levels during physical education have been documented to be low, we hypothesize that the physical activity during physical education still makes a significant contribution to overall physical activity, especially in overweight children.

The purpose of the present study was therefore to assess physical activity during regular physical education lessons in randomly selected first- and fifth-grade schoolchildren and to determine to what degree physical education contributes to overall physical activity, with a special focus on overweight children.

MATERIALS AND METHODS

Participants

Data were taken from two different studies performed in Switzerland. The first population was derived from the Kinder- und Jugendsport-Studie (KISS)(15), including 28 Swiss school classes stratified by age (first and fifth grade classes), geographic region (urban vs. rural) and the prevalence of 10-30% children with migration background. In total, this study comprised 540 children (44.2% first graders, 48.8% boys). The second population set was derived from an unpublished master thesis. To be representative of the cultural differences among Switzerland, 50 randomly selected school directors of primary schools (ranging from first to sixth grade) of three provinces from the German part, two from the French part and one from the Italian part were approached by a letter of invitation. Among them 15 school directors were willing to participate and a total of 31 randomly selected classes from five provinces were included into analysis. The stratified sampling procedure included the same criteria as used for the first data set. This sample included 360 children (46.1% first graders, 49.7% boys). Thus, a total of 900 children, aged 6.9 ± 0.5 years (range 5.3 to 9.9) for first grade children and 11.1 ± 0.6 years (range 9.3 to 13.1) for fifth grade children, and representative of the Swiss population with respect to the living area and ethnicity took part in the present study. All children and their parents gave verbal and written consent to the study. Both studies were approved by the respective local ethical committees.

Anthropometry

All measures were taken in schools by trained study investigators who were blinded in respect of the physical activity behavior of the children. Standing height was measured by a wall-mounted Stadiometer (accuracy ± 0.2 cm) and body weight was determined with an electronic scale (Seca, Basel, Switzerland; accuracy ± 0.1 kg). Height and weight of the children were assessed barefoot in T-shirt and shorts. Body mass index (BMI) was calculated by dividing body weight by height (kg/m^2). BMI z-scores were derived according to Swiss reference data(16). In these, overweight was defined as a BMI z-score above the 90th percentile.

Physical education lessons and physical activity measurements

The Swiss school curriculum schedules three coeducational physical education lessons per week with a duration of 45 or 50 minutes. The customary point of reference for physical education in Switzerland is “moving” which includes the various forms of the normative sport as a central subarea. There are no specific contents to be held in physical education, the perspectives include more comprehensive personality development goals as development of health (fitness/well-being), cooperation (sociability/teamwork), performance (competition, success), expression (presentation/creation), impression (physical/material experiences) and suspense (risk/adventure)(8). The lessons are taught by the classroom teachers and are usually provided on three different weekdays, which balances days with and without physical education. To ensure that teachers performed a normal physical education lesson, teachers and children were blinded to the aim of measuring physical activity during physical education. They did only know that overall physical activity was measured. The class time tables were collected only after the measurements. Normal physical education activities in this age range are playing games, coordination skills, track and field activities etc.

Physical activity was assessed by an accelerometer (MTI/CSA 7164 and GT1M, Actigraph, Shalimar, FL, USA), which was worn at the hip. Because the first study had another principal aim, namely to test a physical activity intervention at school, we included 7 days of measurement in order to ensure to have measured the whole period of school days. However, because the aim of this analysis was compare weekdays with and without physical education, we analysed weekdays only. In the second sample the main aim was to test physical activity contribution of physical education to overall physical activity. For this purpose, we decided to measure a minimum of 4 days with the inclusion of a minimum of two days with and without physical education. A minimum of four measurement days has been recommended to reach a sufficient reliability, i.e. an intraclass correlation coefficient (ICC) of 0.8 among days[17]. The sampling epoch was set at 1 min for KISS and at 15 s for the remaining children. At the start of the first study, an epoch time of 1 min was chosen in order to be comparable with other large studies[2, 7] and to be able to store accelerometer data of a whole week. The second study was a-priori designed to determine physical activity levels during physical education lessons and to measure over a period of only 4 days. We therefore decided to use a smaller epoch time as this was acknowledged in the literature[18] and also under the assumption that 15 sec could be converted into 1 min intervals. Data were included if accelerometer data with at least three full weekdays with a minimum of 12 hours each were available. Based on the findings of our pilot work, time periods with over 15 minutes of continuous zero values were considered to represent periods when the monitors were not worn and, therefore, omitted from further analyses.

Whole-day physical activity was computed between the beginning and the end of activity recording, or, if the accelerometer was worn during the night, individually determined with a specific algorithm: awaking time was suggested, when 2 consequent 30 min periods contained at least 10 active minutes (any counts >0), and a period of three consecutive minutes with ≥20 counts per minute (cpm). The algorithm was tested in pilot work and showed that by this procedure waking and sleeping times were not different between assessment though accelerometers and report by the children or parents, respectively. Whole-day physical activity (TPA_{DAY}) and physical activity during physical education lessons (TPA_{PE}) were expressed as average cpm. Minutes spent in MVPA were defined as activities ≥2000 counts per minutes (first study sample), or >500 counts/15 seconds (second study sample)[7] for the whole-day ($MVPA_{DAY}$) and during physical education lesson ($MVPA_{PE}$).

Statistical Analysis

The data of the two samples were pooled because children did not differ according to age, gender distribution, weight and height, nor there were differences in physical activity variables. Data are shown as means ± standard deviation, unless stated differently. Differences between age groups, gender, and weight status were tested using mixed linear regression models with physical activity variables as outcome variables, and gender, grade and weight status (normal vs. overweight) as independent variables. All analyses were additionally adjusted for study (study population 1 vs. study population 2) and as school class was the smallest cluster in the sampling design, it was therefore introduced as a random effect. Differences between days with and days without physical education were obtained using the same linear regression model with the physical activity difference as dependent variable. Analyses were performed using Stata version 11.0 and the significance level was set at $p<0.05$.

RESULTS

Participants

Of the 900 children in the 59 participating classes, 119 (13.2%) refused to participate. Another 39 (4.3%) children could not be included for analyses because of incomplete data (absent for anthropometric measurements, no information available about physical education lessons), 44 children (4.9%) did not have enough valid accelerometer data (e.g. only one or two days with at least 12 recorded hours) and 22 children (2.4%) were excluded because they had no physical activity data on days with physical education lessons. Therefore, data of 676 children (75.1%) were included into analysis. On average, children had 4.1 ± 1.0 days with valid accelerometer data including 2.3 ± 0.7 days with physical education lessons. A total of 1566 days with physical education and 1183 days without physical education could be included into analysis. Participants' characteristics and overall physical activity levels stratified by gender, grade and weight status are shown in Table 5.1. The characteristics of the children included into analysis did not differ in gender, grade, age, weight, height and BMI from those who were excluded.

Physical activity during physical education lessons

Table 5.2 provides information about the characteristics of the physical education lessons. Overall, children spent 32.8 ± 15.1% of the physical education time in MVPA. Gender was significantly associated with $MVPA_{PE}$ with boys spending 3.3 min (95% confidence interval (CI) 2.5 to 4.2; p<0.001) more in $MVPA_{PE}$ than girls. Grade and weight status were not associated with differences in TPA_{PE} and $MVPA_{PE}$. The Healthy People 2010[19] guideline of at least 50% of physical education time spent in MVPA was achieved by 13.8% of all children. ICC of $MVPA_{PE}$ was 46.4%.

Contribution of physical activity during physical education to daily physical activity and a comparison of physical-education-days versus non-physical-education-days

Overall

Children were significantly more active on days with physical education compared to days without physical education (difference in TPA_{DAY}: 95 cpm (79 to 110; p<0.001) and 16.1 min (13.9 to 18.4; p<0.001) in $MVPA_{DAY}$) (Figure 5.1). TPA_{DAY} on days with physical education was 807 ± 236 cpm, hereof 101.7 ± 34.2 min in $MVPA_{DAY}$. Thus, the amount of MVPA resulting from PA spent in physical education lessons was 16.8 ± 8.5% ($MVPA_{PE}$/$MVPA_{DAY}$). During a day without physical education, TPA_{DAY} was 711 ± 277 cpm with 85.6 ± 36.8 min in $MVPA_{DAY}$.

Table 5.1 Participants' Characteristics

	Total Sample	Gender		Grade		Weight status	
		Girls	Boys	First	Fifth	Normal weight	Overweight§
n	676	347	329	290	386	520	156
Age (years)	9.3 (2.1)	9.2 (2.1)	9.4 (2.1)	6.9 (0.5)	11.1 (0.6)†	9.3 (2.1)	9.4 (2.2)
Weight (kg)	32.6 (10.1)	32.2 (9.5)	33.0 (10.7)	24.0 (4.2)	39.0 (8.3)†	30.0 (7.8)	41.1 (12.2)‡
Height (cm)	136.7 (13.4)	136.0 (13.4)	137.3 (13.4)	123.2 (5.3)	146.8 (7.3)†	135.7 (13.0)	139.8 (14.1)‡
Body mass index (kg/m2)	17.0 (2.8)	17.0 (2.5)	17.0 (3.0)	15.8 (2.1)	18.0 (2.8)†	16.0 (1.6)	20.5 (3.0)‡
n Boys (%)	329 (49%)	-	-	136 (47%)	193 (50%)	260 (50%)	69 (44%)
n 1st Grade children (%)	290 (43%)	154 (44%)	136 (41%)	-	-	227 (44%)	63 (40%)
n Overweight children (%)§	156 (23%)	87 (25%)	69 (21%)	63 (22%)	93 (24%)	-	-
Overall PA							
TPA_{DAY} (cpm/d)	768 (213)	700 (179)	840 (222)*	832 (198)	720 (211)†	781 (216)	726 (198)‡
$MVPA_{DAY}$ (min/d)	94.7 (32.1)	81.9 (26.2)	108.2 (32.3)*	99.2 (30.0)	91.3 (33.3)†	96.5 (32.1)	88.6 (31.7)‡

Values are means (standard deviations), unless stated differently.
§ defined by Swiss reference data (Prader et al. 1989); overweight equals the 90th percentile or above.
* significant gender differences (p<0.05).† significant differences between grades (p<0.05).‡ significant differences between weight status groups (p<0.05).
PA physical activity; TPA_{DAY} total daily physical activity; $MVPA_{DAY}$ daily moderate-and-vigorous physical activity.

Table 5.2 Physical activity during physical education lessons

	Mean (SD)	Gender		Grade		Weight status	
		β (95% CI)	p-value	β (95% CI)	p-value	β (95% CI)	p-value
Duration PE lessons (min)	49.9 (10.0)	0.0 (-0.1 - 0.2)	0.459	-3.3 (-8.6 - 2.0)	0.224	0.1 (-0.1 - 0.2)	0.430
TPA_{PE} (cpm)	1686 (722)	294 (217 - 371)	<0.001	-89 (-344 - 166)	0.495	-62 (-152 - 29)	0.182
$MVPA_{PE}$ (min)	16.7 (9.2)	3.3 (2.5 - 4.2)	<0.001	-2.5 (-6.1 - 1.2)	0.184	-0.4 (-1.4 - 0.6)	0.461
% of PE spent in MVPA	32.8 (15.1)	6.6 (5.0 - 8.2)	<0.001	-1.7 (-7.2 - 3.7)	0.532	-1.2 (-3.0 - 0.7)	0.214

Values are means (standard deviations) and β-coefficients with their 95% confidence intervals.
Girls, 1st grade and normal weight children served as references.
PE physical education; TPA total physical activity; MVPA moderate-and-vigorous physical activity.

Gender

Both, boys and girls were significantly more active on days with compared to days without physical education (p<0.001; for both, TPA_{DAY} and $MVPA_{DAY}$). Gender was not related to TPA_{DAY} and $MVPA_{DAY}$ difference between physical-education- and non-physical-education-days. The contribution of $MVPA_{PE}$ on $MVPA_{DAY}$ did not differ between boys and girls (β (95%-CI): -0.8% (-1.6 to 0.1; p=0.09)). Both, on days with and on days without physical education, a significant relationship was found between gender and all physical activity variables, with higher scores for boys. Corresponding β (95%-CI) for days with physical education were 138 cpm (106 to 170; p<0.001) for TPA_{DAY} and 25.6 min (21.2 to 30.0; p<0.001) of $MVPA_{DAY}$. For days without physical education, β (95%-CI) were 140 cpm (109 to 170; p<0.001) for TPA_{DAY} and 26.4 min (21.5 to 31.3; p<0.001) of $MVPA_{DAY}$.

Grade

Both, first- and fifth- graders showed higher physical activity levels on days with compared to days without physical education (p<0.001; for both, TPA_{DAY} and $MVPA_{DAY}$). However, grade was not related to the difference in TPA_{DAY} and $MVPA_{DAY}$ between physical-education- and non-physical-education days. On days with physical education, first grade children had higher average TPA_{DAY} (β (95%-CI): 104 cpm (54 to 153; p<0.001)), but not $MVPA_{DAY}$ (β (95%-CI): 6.5 min (-1.7 to 14.6; p=0.12)) than fifth grade children. Fifth graders showed a slightly higher contribution of $MVPA_{PE}$ on $MVPA_{DAY}$ (β (95%-CI): -3.4% (-6.7 to -0.1; p=0.042)). On days without physical education, average TPA_{DAY} (β (95%-CI): 138 cpm (91 to 186; p<0.001)) and $MVPA_{DAY}$ (β (95%-CI): 12.6 min (4.1 to 21.2; p=0.004)) were significantly higher in first grade children than in their older counterparts.

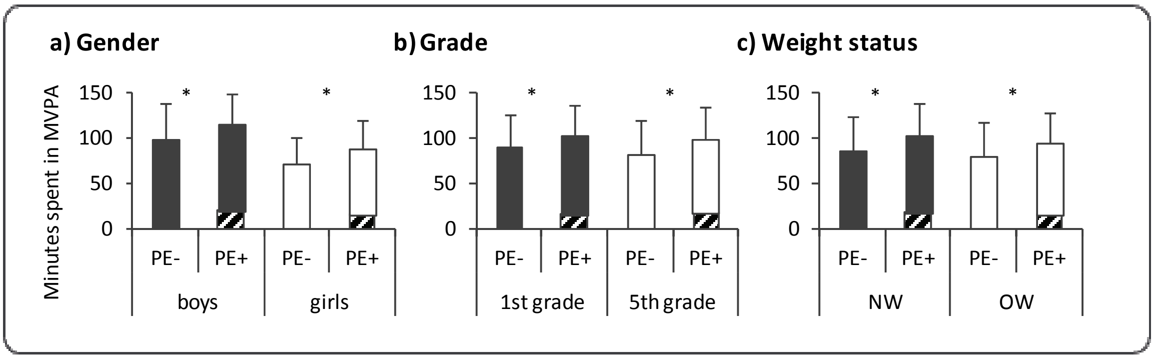

Figure 5.1 Days with physical education lessons vs days without physical education lessons. Minutes spent in moderate-and-vigorous physical activity (MVPA) on days with physical education (PE+) and days without physical education (PE-) analyzed by (a) gender, (b) grade, and (c) weight status. Hatched area is the amount of MVPA spent during the PE lesson. *Indicates statistically significant differences (p<0.05) between PE+ and PE-. NW, normal weight; OW, overweight.

Weight status

Weight status was not linked with differences in physical activity between physical-education- and non-physical-education-days (β (95%-CI): -16.5 cpm (-51.9 to 18.9; p=0.36) for TPA_{DAY} and -2.6 min (-7.7 to 2.5; p=0.32) in $MVPA_{DAY}$, respectively). Both, normal and overweight children spent significantly more time in $MVPA_{DAY}$ (16.8 min (14.3 to 19.4; p<0.001) for normal weight and 13.7 min (9.2 to 18.3; p<0.001) for overweight children) on days with physical education compared to days without physical education. On days with physical education, overweight children were less active than their normal weight counterparts (β (95%-CI): -51 cpm (-89 to -13) for TPA_{DAY} and -7.6 min (-12.8 to -2.4) of $MVPA_{DAY}$, all p<0.01). Overweight children's contribution of $MVPA_{PE}$ on $MVPA_{DAY}$ was higher than in normal-weight children (β (95%-CI): 1.2% (0.1 to 2.2; p=0.028) of minutes in MVPA). On days without PE, weight status was not significantly associated with TPA_{DAY} and $MVPA_{DAY}$ (β (95%-CI) -36 cpm (-72 to 0; p=0.05) and -5.0 min (-10.1 to 0.7; p=0.09), respectively).

DISCUSSION

This cross-sectional study showed that first- and fifth-grade children spent only 33% of physical education time in MVPA. Even though this might seem low, physical education contributed considerably to overall daily physical activity. Furthermore, children performed 16 min more $MVPA_{DAY}$ on days with than without physical education, which was 17% of MVPA of the whole day. Particularly for overweight children, physical education provided an important part of overall MVPA.

$MVPA_{PE}$ has been shown to be small. In a systematic review, Fairclough and Stratton[12] reviewed 44 articles to estimate the physical activity levels during physical education classes and concluded, that on average, children spend 37% of their physical education time in MVPA. More recent data even suggested that $MVPA_{PE}$ levels were not higher than 13% of total time spent in physical education[13, 20]. Despite the fact that Healthy People 2010[19] recommended to increase the proportion of students receiving daily physical education and engage them at least 50% of the physical education time in MVPA, this goal was achieved only by 14% of all children included in the present study. Indeed, there are many different goals to reach in physical education ranging from proficiency in motor skills to social skill development[19] but all physical education goals are achieved by physical activity, therefore not restricting any important aspect of physical education. Nevertheless, the amount of $MVPA_{PE}$ in our study or even the requested 50% of $MVPA_{PE}$ by others can be reached by teaching any pedagogic aspect of physical education as described[8]. One means to increase $MVPA_{PE}$ might be the inclusion of expert physical education teachers who have been effective in well controlled intervention studies[21-24]. Because physical education during primary school is generally given by classroom teachers, education of the classroom teachers might be a cost-effective solution.

It is well documented that boys generally engage in more $MVPA_{DAY}$ than girls[25]. Interestingly, and in contrast with most previous studies[10, 12, 20], boys in our study also spent more time in $MVPA_{PE}$ than girls despite the fact that both genders were co-educated and therefore taught the same lesson. Because there is a consistently higher level of physical activity in males compared to females throughout life and irrespective of context and way of assessment, socio-cultural differences but also a genetic component may play a role[26]. This gender difference is particularly interesting given to the fact that in our study, overweight children could not dodge the physical activity during physical education. Overweight children's $MVPA_{PE}$ did not differ from those of their normal weight counterparts. Nevertheless, overweight children were less physically active outside school hours as reported by others[27]. Because overall physical activity levels of overweight children were found to be lower than those of normal-weight children[7, 28], physical education provides an important opportunity for overweight children to participate in regular and structured physical activity.

Irrespective of gender, grade and weight status, children were significantly more active on days with physical education than on days without physical education. On physical education days, children spent an additional 16 min in $MVPA_{DAY}$. This was, however, the same amount of MVPA that children spent during physical education and therefore, is not compatible with the hypothesis that children would compensate for extra physical activity during physical education by being less physically active after school(14, 29, 30). Andersen et al.(2) assumed that MVPA levels of at least 90 min/d could prevent clustering of cardiovascular disease risk factors in children. Thus, increasing MVPA from 86 to 102 minutes on days with physical education compared to non-physical-education-days might make an important contribution to achieve this recommendation and, thus, to reduce the risk of metabolic disease. On days with physical education, this 90-min-guideline was achieved by 62% of all children (51% of the overweight children), whereas on days without physical education, only 43% of the children (39% of the overweight children) achieved it. The contribution of the physical education lesson to overall physical activity is relevant from a public health perspective because 16 min more of MVPA per day lead to increased fitness and reduced cardiovascular risk in a well-controlled physical activity intervention study(21). The well-known public health principle of Rose(31) shows that even a small shift of the population median, i.e., in the present study 16 min of additional $MVPA_{DAY}$ would be expected to have a considerable impact on public health by shifting the whole population curve into the favorable direction.

There are a few studies examining the contribution of physical education-based physical activity on overall physical activity and children's overall physical activity levels on days with and days without physical education. Wickel et al.(13) showed that in 6- to 12-years-old boys, 11% (12 min) of their $MVPA_{DAY}$ resulted from physical education. This study included only boys that were recruited from sports clubs and measurements included one day in which children participated in an after-school sports club. They possibly represent a selective group and generalization may not be appropriate.

Strengths of this study are the large sample size and its representativeness for the Swiss population with regard to geographic region (i.e., rural vs. urban) and migrant status (10-30% children from other ethnicities). The large sample size allowed comparisons between age groups, genders and children with different weight status. Furthermore, physical activity was assessed by accelerometers, which reduces measurement bias. Children and teachers knew by nature about the function of the accelerometers, but were told that the aim was to assess overall physical activity without mentioning the physical education lessons. There are some limitations that should be considered. Only 75% of the potentially selectable children could be included into analysis, which may reduce the representativeness of the data, although excluded children did not differ in gender, grade, age, weight, height and BMI from the children included to the final sample. Moreover, even if accelerometers have shown to be a valid and reliable measure of physical activity in children and adolescents[32], they have some limitations. During non-weight-bearing activities (i.e., cycling), accelerometers do not assess exercise intensity accurately, which might have resulted in an underestimation of physical activity levels. However, the distribution of these activities not captured well by accelerometry is expected to be random among days with and without physical education. We are aware of the fact that pooling two data sets with different epoch times might be a problem. Both, 15s-epochs and 60s-epochs and mixing them might not be optimal. However, there is still no clear consensus if the choice of a certain epoch time really matters[33]. Moreover, physical activity measurements in the two samples took place during different seasons of the year, i.e., during summer/fall for KISS and during winter/spring for the master thesis. This might have caused a bias because overall physical activity has been shown to vary by season, being higher in summer and lower in winter[34]. Nevertheless, the inclusion of all seasons should have controlled for such a selection bias. In addition, we adjusted our model for the study arm which should have controlled for the seasonal effects. And finally, physical activity was expressed in percent of a child's total physical activity so that the relative contribution was the same irrespective of epoch time.

The content of the physical education lesson might considerably influence the extent of $MVPA_{PE}$, as for example balancing on a beam to improve dynamic balance compared to rope skipping to improve aerobic capacity. While none of the teacher knew about the specific assessment of the physical education lessons we cannot completely rule out a bias towards more active physical education lessons while the accelerometer was worn. To minimize this bias we adjusted for teacher's influence by clustering our data. ICCs during physical education were high, what indicates that the teachers influence and with it the lessons' contents explained a considerable part of physical activity variance.

Our data support the Healthy People 2010[19] guidelines and underlines that physical activity during physical education contributes considerably to overall physical activity of elementary schoolchildren by an extent that has been shown to increase fitness and reduce cardiovascular risk in children[21]. We, therefore, conclude that even if only one third of physical education time is spent in MVPA in elementary school children, physical education provides an important possibility to be active, especially in overweight children.

Perspectives

For a growing number of children, physical education provides the main opportunity for being physically active. It is therefore important to know about the contribution of physical activity during physical education to overall physical activity that is essential to maintain health. From a public health perspective, especially the characteristics of overweight children's physical activity might be important. Compared to the overall amount of physical activity – where overweight children are known to be less active than their normal weight counterparts[7] – overweight children spend the same amount of time in $MVPA_{PE}$ than normal weight children. This knowledge underlines the importance of physical education, especially for overweight children and might help to develop strategies for further intervention studies and public health programs.

REFERENCES

(1) Strong WB, Malina RM, Blimkie CJ, Daniels SR, Dishman RK, Gutin B, et al. Evidence Based Physical Activity for School-Age Youth. J Pediatr. 2005; 146(6): 732.

(2) Andersen LB, Harro M, Sardinha LB, Froberg K, Ekelund U, Brage S, et al. Physical Activity and Clustered Cardiovascular Risk in Children: A Cross-Sectional Study (the European Youth Heart Study). Lancet. 2006; 368(9532): 299.

(3) Pate RR, Davis MG, Robinson TN, Stone EJ, McKenzie TL, Young JC. Promoting Physical Activity in Children and Youth: A Leadership Role for Schools: A Scientific Statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism (Physical Activity Committee) in Collaboration with the Councils on Cardiovascular Disease in the Young and Cardiovascular Nursing. Circulation. 2006; 114(11): 1214.

(4) Pate RR, O'Neill JR. Summary of the American Heart Association Scientific Statement: Promoting Physical Activity in Children and Youth: A Leadership Role for Schools. J Cardiovasc Nurs. 2008; 23(1): 44.

(5) Dollman J, Norton K, Norton L. Evidence for Secular Trends in Children's Physical Activity Behaviour. Br J Sports Med. 2005; 39(12): 892.

(6) Bailey R. Physical Education and Sport in Schools: A Review of Benefits and Outcomes. J Sch Health. 2006; 76(8): 397.

(7) Ekelund U, Sardinha LB, Anderssen SA, Harro M, Franks PW, Brage S, et al. Associations between Objectively Assessed Physical Activity and Indicators of Body Fatness in 9- to 10-Y-Old European Children: A Population-Based Study from 4 Distinct Regions in Europe (the European Youth Heart Study). Am J Clin Nutr. 2004; 80(3): 584.

(8) Puehse U, Gerber M. International Comparison of Physical Education: Concepts, Problems, Prospects. Aachen: Meyer & Meyer; 2005.

(9) Hardman K, Marshall J. Update on the State and Status of Physical Education World-Wide. Berlin; 2005.

(10) Tudor-Locke C, Lee SM, Morgan CF, Beighle A, Pangrazi RP. Children's Pedometer-Determined Physical Activity During the Segmented School Day. Med Sci Sports Exerc. 2006; 38(10): 1732.

(11) National Association for Sport and Physical Education. Moving into the Future: National Standards for Physical Education. 2nd ed. Boston: McGraw-Hill; 2004.

(12) Fairclough SJ, Stratton G. A Review of Physical Activity Levels During Elementary School Physical Education. J Teach Phys Educ. 2006; 25(2): 239.

(13) Wickel EE, Eisenmann JC. Contribution of Youth Sport to Total Daily Physical Activity among 6- to 12-Yr-Old Boys. Med Sci Sports Exerc. 2007; 39(9): 1493.

(14) Mallam KM, Metcalf BS, Kirkby J, Voss LD, Wilkin TJ. Contribution of Timetabled Physical Education to Total Physical Activity in Primary School Children: Cross Sectional Study. Br Med J. 2003; 327(7415): 592.

(15) Zahner L, Puder JJ, Roth R, Schmid M, Guldimann R, Puhse U, et al. A School-Based Physical Activity Program to Improve Health and Fitness in Children Aged 6-13 Years ("Kinder-Sportstudie Kiss"): Study Design of a Randomized Controlled Trial [Isrctn15360785]. BMC Public Health. 2006; 6: 147.

(16) Prader A, Largo RH, Molinari L, Issler C. Physical Growth of Swiss Children from Birth to 20 Years of Age. First Zurich Longitudinal Study of Growth and Development. Helv Peadiatr Acta Suppl. 1989; 52: 1.

(17) Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using Objective Physical Activity Measures with Youth: How Many Days of Monitoring Are Needed? Med Sci Sports Exerc. 2000; 32(2): 426.

(18) Rowlands AV. Accelerometer Assessment of Physical Activity in Children: An Update. Pediatr Exerc Sci. 2007; 19(3): 252.

(19) US Department of Health and Human Services. Healthy People 2010: Understanding and Improving Health. In: Services USDoHaH, editor. 2nd ed. ed. Washington, DC: U. S. Government Printing Office; 2000. p. 1.

(20) Nettlefold L, McKay HA, Warburton DE, McGuire KA, Bredin SS, Naylor PJ. The Challenge of Low Physical Activity During the School Day: At Recess, Lunch and in Physical Education. Br J Sports Med. 2010.

(21) Kriemler S, Zahner L, Schindler C, Meyer U, Hartmann T, Hebestreit H, et al. Effect of School Based Physical Activity Programme (Kiss) on Fitness and Adiposity in Primary Schoolchildren: Cluster Randomised Controlled Trial. Br Med J. 2010; 340(feb23 1): c785.

(22) McKenzie TL, Sallis JF, Kolody B, Faucette FN. Long-Term Effects of a Physical Education Curriculum and Staff Development Program: Spark. Res Q Exerc Sport. 1997; 68(4): 280.

(23) McKenzie TL, Stone EJ, Feldman HA, Epping JN, Yang M, Strikmiller PK, et al. Effects of the Catch Physical Education Intervention: Teacher Type and Lesson Location. Am J Prev Med. 2001; 21(2): 101.

(24) Kriemler S, Meyer U, Martin E, van Sluijs EM, Andersen LB, Martin BW. Effect of School-Based Interventions on Physical Activity and Fitness in Children and Adolescents: A Review of Reviews and Systematic Update. Br J Sports Med. 2011; 45(11): 923.

(25) Trost SG, Pate RR, Sallis JF, Freedson PS, Taylor WC, Dowda M, et al. Age and Gender Differences in Objectively Measured Physical Activity in Youth. Med Sci Sports Exerc. 2002; 34(2): 350.

(26) Maia JA, Thomis M, Beunen G. Genetic Factors in Physical Activity Levels: A Twin Study. Am J Prev Med. 2002; 23(2 Suppl): 87.
(27) Fairclough S, Stratton G. Physical Activity, Fitness, and Affective Responses of Normal-Weight and Overweight Adolescents During Physical Education. Pediatr Exerc Sci. 2006; 18(1): 53.
(28) Trost SG, Kerr LM, Ward DS, Pate RR. Physical Activity and Determinants of Physical Activity in Obese and Non-Obese Children. Int J Obes Relat Metab Disord. 2001; 25(6): 822.
(29) Rowland TW. The Biological Basis of Physical Activity. Med Sci Sports Exerc. 1998; 30(3): 392.
(30) Donnelly JE, Jacobsen DJ, Whatley JE, Hill JO, Swift LL, Cherrington A, et al. Nutrition and Physical Activity Program to Attenuate Obesity and Promote Physical and Metabolic Fitness in Elementary School Children. Obes Res. 1996; 4(3): 229.
(31) Rose G. Rose's Strategy of Preventive Medicine. 2nd ed: Oxford University Press; 2008.
(32) Trost SG, Ward DS, Moorehead SM, Watson PD, Riner W, Burke JR. Validity of the Computer Science and Applications (Csa) Activity Monitor in Children. Med Sci Sports Exerc. 1998; 30(4): 629.
(33) McClain JJ, Abraham TL, Brusseau TA, Jr., Tudor-Locke C. Epoch Length and Accelerometer Outputs in Children: Comparison to Direct Observation. Med Sci Sports Exerc. 2008; 40(12): 2080.
(34) Mattocks C, Leary S, Ness A, Deere K, Saunders J, Kirkby J, et al. Intraindividual Variation of Objectively Measured Physical Activity in Children. Med Sci Sports Exerc. 2007; 39(4): 622.

CHAPTER 6

Effect of a school-based physical activity program (KISS) on fitness and adiposity in primary school children: a cluster-randomized controlled trial

Susi Kriemler
Lukas Zahner
Christian Schindler
Ursina Meyer
Tim Hartmann
Helge Hebestreit
Hans Peter Brunner-La Rocca
Willem van Mechelen
Jardena J. Puder

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EFFECT OF A SCHOOL-BASED PHYSICAL ACTIVITY PROGRAM ON FITNESS AND ADIPOSITY IN PRIMARY SCHOOL CHILDREN: A CLUSTER-RANDOMIZED CONTROLLED TRIAL

ABSTRACT

Objective To assess the effectiveness of a school-based physical activity program during one school-year on physical and psychological health in young schoolchildren. **Design** Cluster randomized controlled trial. **Setting** 28 classes from 15 elementary schools in Switzerland randomly selected and assigned in a 4:3 ratio to an intervention (n=16) or a control arm (n=12) after stratification for grade (first and fifth grade), from August 2005 to June 2006. **Participants** 540 children, of whom 502 consented and presented at baseline. **Intervention** Children in the intervention arm (n=297) received a multi-component physical activity program that included structuring the three existing physical education lessons each week and adding two additional lessons a week, daily short activity breaks, and physical activity homework. Children (n=205) and parents in the control group were not informed of an intervention group. For most outcome measures, the assessors were blinded. **Main outcome measures** Primary outcome measures included body fat (sum of four skinfolds), aerobic fitness (shuttle run test), physical activity (accelerometry), and quality of life (questionnaires). Secondary outcome measures included body mass index and a cardiovascular risk score (average z-score of waist circumference, mean blood pressure, blood glucose, inverted high density lipoprotein cholesterol, and triglycerides). **Results** 498 children completed the baseline and follow-up assessments (mean age 6.9 (SD 0.3) years for first grade, 11.1 (0.5) years for fifth grade). After adjustment for grade, sex, baseline values and clustering within classes, children in the intervention arm compared with controls showed more negative changes in the z-score of the sum of four skinfolds (-0.12, 95% confidence interval -0.21 to -0.03; p=0.009). Likewise, their z-scores in aerobic fitness increased more favourably (0.17, 0.01 to 0.32; p=0.04), as did those for moderate-vigorous physical activity in school (1.19, 0.78 to 1.60; p<0.001), all day moderate-vigorous physical activity (0.44, 0.05 to 0.82; p=0.03), and total physical activity in school (0.92, 0.35 to 1.50; p=0.003). Z-scores in overall daily physical activity (0.21, -0.21 to 0.63) and physical quality of life (0.42,-1.23 to 2.06) as well as psychological quality of life (0.59, -0.85 to 2.03) did not change significantly. **Conclusions** A school-based multi-component physical activity intervention including compulsory elements improved physical activity and fitness and reduced adiposity in children.

INTRODUCTION

One of three to five children in the Western world is overweight or obese[(1)]. This epidemic is rapidly and constantly growing and affects all socioeconomic levels and ethnicities[(2)]. Excessive weight is associated with increased cardiovascular risk[(3)], orthopaedic problems, and psychosocial constraints even before adulthood is reached[(4)]. Life expectancy may be reduced by several years[(5)], as is work productivity, while costs are increasing enormously. A focus on early prevention is thus urgently needed.

The increase in physical inactivity over the last decades is one of the main causes of the increase in obesity[6]. In adults, physical inactivity and low aerobic fitness are associated with higher mortality and a higher prevalence of chronic disease[7]. In children, physical inactivity and lack of fitness are associated with increasing prevalence of cardiovascular risk factors[3, 8], even independent of body weight[9].

As obesity, cardiovascular risk factors, and risk behaviour usually change little from childhood to adulthood[10, 11], promotion of positive health-related behaviour in early life is important and expected to have long-term benefits. However, studies of school-based interventions promoting a healthy lifestyle have shown disappointing results[12, 13], and these trials have often had important methodological or conceptual limitations that should be overcome in future research[14]. A theory driven, randomized, controlled physical activity intervention in youth with a global assessment of cardiovascular risk factors is still lacking.

Our goal was to intervene at the level of the school class, so we did a cluster-randomized controlled trial with a school-based stringent physical activity program versus traditional physical education during one school-year. We aimed to increase aerobic fitness, physical activity, and quality of life while decreasing body fat and a composite cardiovascular risk factor score in the intervention group compared with the control group.

METHODS

Design and study population

The study took place in two of the 26 provinces of Switzerland (Aargau and Baselland), comprising about 10% of the Swiss population. Recruitment started in automn 2004, and the actual study took place between August 2005 and July 2006. The design of the study has been previously described in detail[15], and Figure 6.1 describes the selection process. We selected 28 of 190 consenting classes on the basis of a computer-generated random number table that was in the hands of a person not involved in the study. Participating schools fulfilled our eligibility criteria: rural or urban localization, a prevalence of 10-30% migrants as in the Swiss population, and, for practical reasons, the presence of at least a first and a fifth grade class in each school (Figure 6.1). Intervention and control classes were located in provinces that were comparable as regards socioeconomic status of the population and recreational facilities at school. To avoid contamination of treatments, we randomized by school. However, the school director had no role during the whole study period, and all parts of the intervention were done at the class level. Classes from the intervention and control groups were located in different villages or towns. All participating children and their parents gave informed consent.

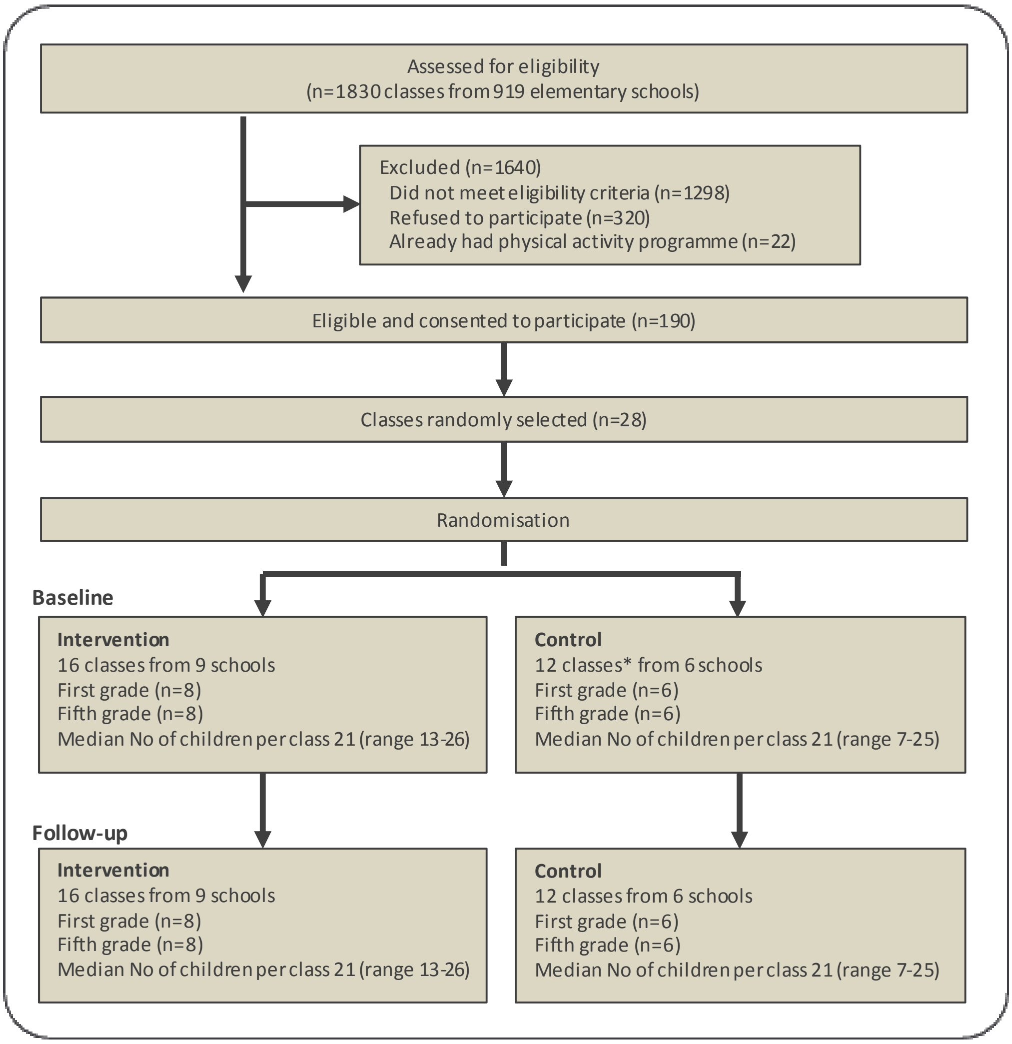


Figure 6.1 Flow of school classes through study (study cluster). *Contrary to protocol, in which one control class was misclassified, 12 (not 11) classes were randomized to control group.

Intervention

The intervention was targeted at both the cluster and the individual level and was based on a socio-ecological conceptual model focusing on increasing daily physical activity[16], as described previously[15] and in Figure 6.2. Briefly, children in both groups had three physical education lessons each week, which are compulsory by law. The intervention group had two additional physical education lessons on the remaining school days. A team of expert physical education teachers prepared all five physical education lessons for the children in the intervention group. All intervention classes received the same curriculum. The three compulsory weekly physical education lessons (45 minutes each) were given by the usual classroom teachers according to the specified curriculum, whereas the two additional weekly lessons (45 minutes each) were taught mostly outdoors by physical education teachers. In addition, three to five short activity breaks (two to five minutes each) during academic lessons – comprising motor skill tasks such as jumping or balancing on one leg, power games, or coordinative tasks – were introduced every day. The children received daily physical activity homework of about 10 minutes' duration prepared by the physical education teachers. This included aerobic, strength, or motor skill tasks such as brushing their teeth while standing on one leg, hopping up and down the stairs, rope jumping or comparable activities. Children and parents of the control group were not informed about the existence of the intervention program in other schools. The teachers in the control group knew about the intervention arm but were not informed about its content. No incentives for participating in the study were offered to the children.

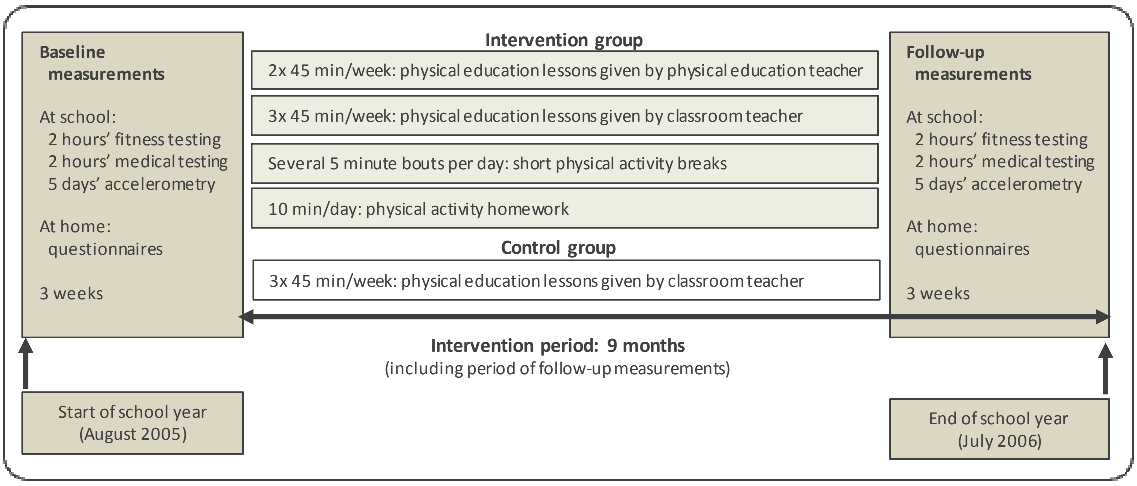


Figure 6.2 Content and timetable of intervention.

Outcome measures

Baseline (August 2005) and follow-up (June 2006) measurements took place at school within the same three week period for all children; the intervention period lasted nine months. All assessors were trained in a pilot study two months before the main study. Assessors responsible for the measurements were blinded to the group allocation for all measurements except skinfold and waist circumference measures. School laws prescribed that the last two measurements were made by designated physicians who knew the group allocation. Outcome measures are reported at the individual level. Primary outcome measures included the sum of four skinfolds, aerobic fitness, physical activity and quality of life. Secondary outcome measures included body mass index and a cardiovascular risk score comprising all components of the metabolic syndrome. Additional predefined secondary outcomes such as bone mineral content and density, as well as bone turnover markers and calcium intake, will be reported separately.

We calculated the percentage of overweight children on the basis of Swiss national percentiles[17]. Skinfold thickness was measured in triplicate to the nearest 0.5 mm with Harpenden calipers (HSK-BI, British Indicators). We calculated the sum of four sites (triceps, biceps, subscapular and suprailiacal)[18]. We used the 20 m shuttle run test to determine aerobic fitness[19]. Ten children did the test together, but each child had a researcher assigned who was checking adequate test procedures. We monitored physical activity with an accelerometer (MTI/CSA 7164, Actigraph, Shalimar, FL, USA), which was worn continuously around the hip for five weekdays, at baseline and at the end of the intervention. We set the sampling epoch to one minute. We omitted time periods with over 15 minutes of continuous zero values. We included an individual child's physical activity data if at least two weekdays of measurements with a minimum of 12 hours were recorded(20). In addition, weekdays had to include at least one physical education lesson. In case of missing data (measurement of less than five days), we averaged the number of days with and without physical education separately and, on the basis of the class schedule, extrapolated them to a school-week of five days. Eighty-nine per cent of all children had three to five monitoring days on both occasions, 11% had two monitoring days (that is, 6.8% imputed days), which is sufficient to be representative for the school week(8), especially as the amount of physical activity among the single school days did not differ(21). At baseline, the number of missed measurement days with and without physical education did not differ between the groups. We expressed physical activity as average counts/minute and moderate-vigorous physical activity as minutes above 2000 counts/minute (which is equivalent to walking at about 4 km/hour) for the whole day, the time in school and the time out of school. We assessed quality of life with the child health questionnaire(22), distributed at school in coded envelopes and completed by the child, with the help of the parents if necessary.

We measured blood pressure in the right arm five times after a resting period of five minutes by using an automated oscillograph (Oscillomate, CAS Medical Systems, Branford, CT, USA). We took the mean of the three measurements with the smallest variation and then z-transformed it(23). Blood was drawn in the morning while the child was fasting for measurements of glucose and lipids as previously described(15). Although not specified in the paper describing the study design, we computed a composite cardiovascular risk score by averaging the z-scores of all components of the metabolic syndrome (waist circumference, blood pressure (mean of systolic and diastolic blood pressure z-score), glucose, inverted high density lipoprotein cholesterol, and triglycerides)(24). We log-transformed skewed data. We derived z-scores from published age and sex specific norm values for body mass index and blood pressure(23, 25). We z-transformed the remaining variables by using grade- and sex-specific means and standard deviations derived from the whole sample for the baseline measurements and from the control sample for the post-intervention measurements. At the end of the study, we asked children and teachers of the intervention group about their enjoyment of the program and whether they wanted the program to continue in the future by using a six-point scale ranging from 1 (very much) to 6 (not at all).

Statistical analysis

We based statistical analyses on the intention-to-treat principle and report results at the level of individual children. We used a regression model with adjustment for cluster to compare baseline measurements of the two groups. As the study population consisted of two distinct age groups, all analyses estimating effects of the intervention on outcomes used z-scores based on grade and sex. We used mixed linear models with z-scores at follow-up as dependent variables; group, sex, and grade as fixed factors; school class as random effect; and the respective baseline z-score as covariate. School class was the smallest cluster in the sampling design, so we introduced it as a random effect. We calculated the intraclass correlation coefficients to compare the variation between school classes as a fraction of the total variance. We also tested whether the additional cluster 'school' influenced the results. We did not include pubertal stage according to Tanner stage, migrant status, or socioeconomic status as covariates, as their addition to the model did not change the results. For each outcome measure, we reported the size of the intervention effect as the difference in its average z-scores at follow-up between the intervention and control group after adjustment for grade, sex, baseline values, and clustering within school classes. We did secondary analyses by testing interactions of the intervention with sex, grade, and baseline body mass index, categorized into two groups above and below the median[25].

We based our sample size calculation on a predefined ratio of 4:3 between intervention and control schools each contributing two classes of 20 children. The study was powered to detect a medium effect size on the primary study outcome measures of 0.5 units of standard deviation with 79% probability if the intraclass correlation coefficient within schools was 0.10 and with 90% probability for a coefficient of 0.06 for each primary outcome measure. The sample size needed to reach the estimated power was a total of 360 children at the third measurement, four years after baseline assessment. Assuming an attrition rate of 10-15% and accounting for the multiple secondary outcomes, we recruited 540 children to provide adequate power to test the null-hypothesis of the intervention having no effect for each of the primary outcomes.

RESULTS

Twenty-eight classes in 15 schools totalling 540 children entered the study. Figure 6.1 and 6.3 give sample size information throughout the trial. Table 6.1 shows baseline characteristics stratified by allocation arm and grade. Tables 2 and 3 describe primary and secondary outcomes at baseline and follow-up. No significant differences existed between the groups at baseline. This is also true for the z-scores of total physical activity in school, which were 0.01 (SD 0.99) for the children in the intervention group and -0.02 (SD 1.02) for those in the control group (p=0.76). Moreover, children with baseline assessment but no follow-up assessment did not differ from the remaining children in age, sex, and the primary and secondary outcome variables at baseline (data not shown).

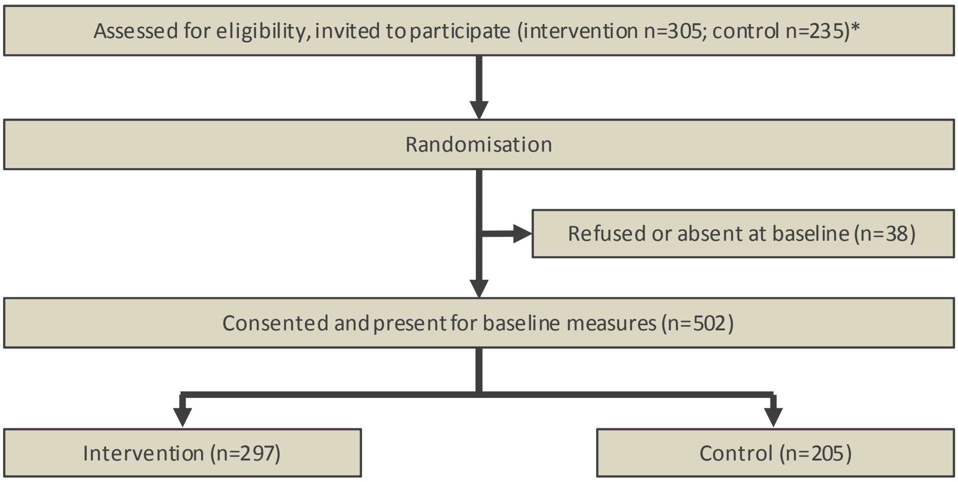
Primary outcomes

Table 6.2 shows the results of the primary outcomes at baseline and follow-up, as well as the adjusted differences at follow-up. Compared with controls, children in the intervention group showed smaller increases in the sum of four skinfolds by 0.12 (95% confidence interval -0.21 to -0.03) z-score units, corresponding to about 2 mm (or 6% of the mean baseline value). Four control children and five intervention children were underweight (below the third centile for weight) at baseline; the prevalence of underweight did not increase in either group. The intervention increased children's aerobic fitness by 0.17 (0.01 to 0.32) z-score units, representing an improvement of 5% of mean baseline values. This effect corresponds to an increase in running time of 20 seconds. The change in moderate-vigorous physical activity from baseline to follow-up was significantly higher in the intervention group: the difference in average z-score for in-school activity was 1.19 (0.78 to 1.60), corresponding to about 13 additional minutes, and that for all day activity was 0.44 (0.04 to 0.82), corresponding to 11 additional minutes. Likewise, the change in total physical activity in school was higher in the intervention group than in the control group, corresponding to a relative increase of 18% - that is, a shift of the median to the 82nd centile. However, the change in overall daily physical activity from baseline to follow-up showed only a non-significant trend in favour of the intervention group. Effects of the intervention on primary outcomes were comparable in children with and without complete physical activity data (all $p>0.3$). Quality of life did not change in the two groups. The intraclass correlations coefficients were ≤0.1, indicating a low level of clustering within school classes, except for total physical activity for which the coefficient was larger (0.09-0.24). An additional adjustment of all primary outcome analyses for the random effect of 'school' showed no further variance for those primary outcomes that were significantly improved by the intervention. The factor 'school' had an effect only on physical quality of life, for which it explained 2% of the residual variance.

Table 6.1 Baseline characteristics of 502 elementary schoolchildren according to treatment arm and grade. Values are numbers (percentages) unless stated otherwise.

	First grade		Fifth grade	
	Intervention (n=131)	Control (n=91)	Intervention (n=166)	Control (n=114)
Girls	64 (49)	50 (55)	91 (55)	52 (46)
Mean (SD) age (years)	6.9 (0.3)	6.9 (0.3)	11.0 (0.5)	11.3 (0.6)
Overweight*	34 (26)	26 (29)	41 (25)	28 (25)
Tanner stage >1	0	0	83 (50)	54 (48)
Migrant families†	45 (34)	23 (26)	41 (25)	27 (24)
No formal parental education	12 (9)	4 (5)	19 (12)	12 (11)

*Based on Swiss national centiles.
†Both parents from Eastern or Southern European countries, Africa, Asia, Central or South America, or other less developed countries.



Before	After	Both	Primary outcomes	Before	After	Both
296	293	284	Skinfolds	201	205	185
297	278	267	Fitness	205	192	181
218	229	169	Physical activity	134	106	82
286	264	257	Quality of life	170	173	154
			Secondary outcomes			
249	239	231	Cardiovascular risk score	117	121	105
296	293	284	Body mass index	201	205	185
294	293	286	Blood pressure	201	205	185
291	292	282	Waist circumference	201	205	185

Figure 6.3 Flow of individual participants through study, with outcome measures. *Contrary to protocol, 28 (not 27) classes were randomized, 16 classes with 305 (not 300) to intervention group and 12 (not 11) classes with 205 children to control group; furthermore, one child was misclassified as in intervention instead of control group.

Secondary outcomes

Table 6.3 shows the baseline and follow-up data and the adjusted differences at follow-up for cardiovascular risk factors in both groups. Children in the intervention group showed smaller increases or larger reductions in body mass index and in most cardiovascular risk factors such as triglycerides, high density lipoprotein cholesterol, and glucose. The cardiovascular risk score was decreased more in the intervention than in the control group, corresponding to 0.18 (-0.29 to -0.06) z-score units and representing a shift from the median to the 36th centile (that is, 14%). This finding remained unchanged when we standardized waist circumference on the basis of a reference population or when we replaced waist circumference by body mass index z-scores[25, 26]. Secondary analyses also involved the study of potential modifications of the effect by sex, grade, or baseline body mass index (dichotomized at the median)[25]. The intervention by grade interaction was significant for the sum of four skinfolds (p=0.003), with a stronger intervention effect in fifth grade children. All other interactions had p-values larger than

0.1. Ninety per cent of the children and 70% of the teachers in the intervention group enjoyed the five physical education lessons and wanted them to continue in future years (scores of 1-2 for children and 1-3 for teachers on a six-point scale).

Table 6.2 Primary outcome measures in children according to physical activity intervention aimed at increasing physical activity and fitness and at reducing body fat and cardiovascular risk score. Values are mean (SD) unless stated otherwise.

	Intervention		Control		Adjusted difference at follow-up*		
Variables	Before	After	Before	After	Coefficient (95% CI)	P value	ICC
Skinfolds (mm)	32.11 (13.23)	32.50 (14.67)	31.32 (12.82)	33.70 (17.24)	-0.12 (-0.21 to -0.03)	0.009	0.06
Shuttle run (stages)	5.6 (2.3)	6.8 (2.2)	5.8 (2.1)	6.7 (1.9)	0.17 (0.01 to 0.32)	0.04	0.03
Total physical activity (counts/min)	770 (197)	726 (181)	792 (204)	728 (225)	0.21 (-0.21 to 0.63)	0.31	0.15
In school	807 (276)	870 (217)	828 (292)	738 (235)	0.92 (0.35 to 1.5)	0.003	0.24
Out of school	755 (217)	653 (197)	777 (209)	722 (248)	-0.14 (-0.51 to 0.22)	0.41	0.09
Total MVPA (min/day)	106 (36)	106 (34)	106 (33)	97 (34)	0.44 (0.05 to 0.82)	0.03	0.08
In school	38 (16)	45 (14)	37 (14)	32 (12)	1.19 (0.78 to 1.60)	<0.001	0.11
Out of school	67 (27)	61 (25)	69 (25)	66 (28)	-0.06 (-0.39 to 0.27)	0.72	0.06
Physical quality of life	53.4 (8.9)	53.7 (8.7)	53.2 (7.7)	53.9 (6.5)	-0.42 (-1.23 to 2.06)	0.72	0.00
Psychological quality of life	52.5 (6.9)	52.3 (7.7)	53.0 (6.5)	52.0 (7.3)	0.59 (-0.85 to 2.03)	0.42	0.02

ICC=intraclass correlation coefficient; MVPA=moderate and vigorous physical activity.
*Adjusted difference in average z-score of respective outcome at follow-up between intervention and control group with 95% confidence interval, P value, and ICC for school class; adjusted for grade, sex, and z-score at baseline in mixed linear model with random effect for school class.

Table 6.3 Secondary outcome measures in children according to physical activity intervention aimed at increasing physical activity and fitness and at reducing body fat and cardiovascular risk score*. Values are mean (SD) unless stated otherwise.

	Intervention		Control		Adjusted difference at follow-up*		
Variables	Before	After	Before	After	Coefficient (95% CI)	P value	ICC
Cardiovascular risk score	0.01 (0.49)	-0.27 (0.44)	0.06 (0.53)	-0.03 (0.51)	-0.18 (-0.29 to -0.06)	0.003	0.06
Body mass index (kg/m^2)	17.13 (2.53)	17.36 (2.67)	17.04 (2.63)	17.44 (2.89)	-0.12 (-0.19 to -0.04)	0.003	0.01
Waist circumference (cm)	57.95 (6.94)	59.45 (6.87)	57.66 (6.43)	59.86 (7.39)	-0.08 (-0.2 to 0.05)	0.25	0.17
Systolic blood pressure (mm Hg)	104 (9)	101 (9)	103 (8)	102 (9)	-0.08 (-0.26 to 0.23)	0.88	0.19
Diastolic blood pressure (mm Hg)	62 (8)	60 (7)	61 (7)	61 (8)	-0.12 (-0.35 to 0.10)	0.28	0.20
Triglycerides (mmol/l)	0.60 (0.25)	0.60 (0.25)	0.64 (0.29)	0.69 (0.32)	-0.10 (-0.18 to -0.01)	0.02	0.00
HDL cholesterol (mmol/l)	1.65 (0.35)	1.68 (0.35)	1.60 (0.35)	1.55 (0.37)	0.27 (0.09 to 0.44)	0.003	0.05
Glucose (mmol/l)	4.5 (0.4)	4.6 (0.3)	4.6 (0.4)	4.7 (0.4)	-0.40 (-0.70 to -0.09)	0.01	0.10

HDL=high density lipoprotein; ICC=intraclass correlation coefficient.
*Average z-score of waist circumference, mean of systolic and diastolic blood pressure z-score, glucose, triglycerides, and inverse HDL-cholesterol.
*Adjusted difference in average z-score of respective outcome at follow-up between intervention and control group with 95% confidence interval, P value, and ICC for school class; adjusted for grade, sex, and z-score at baseline in mixed linear model with random effect for school class.

DISCUSSION

This randomized controlled trial showed that a multi-component physical activity intervention for one school year in first and fifth grade schoolchildren favourably affected body composition, aerobic fitness, physical activity, and cardiovascular risk. Our program resulted in a relative decrease (that is, a lesser increase) in body fat in the intervention compared with the control group. These findings were consistent for body mass index and skinfold thickness. The favourable changes in body composition occurred in children across the whole range of body mass index and did not increase the number of underweight children. Establishing a program with consistent positive effects on body composition is of major public health importance; in well-designed reviews, only very few lifestyle or physical activity intervention programs were considered effective in reducing body fat or body mass index in schoolchildren(13, 27). The absolute effect of our intervention on body fat seems small, with a difference of skinfold thickness of about 2 mm between children in the intervention and control groups. However, this corresponds to 6% of the average baseline value and it was achieved within less than one year in otherwise healthy children. The effect is similar to that in a few comparable intervention studies but is higher than that in most other studies(13, 28). This is an important result for public health, as a higher body mass index in childhood, even in the absence of overt overweight, has been associated with coronary heart disease in adulthood(29). In addition, a higher body mass index in adolescence predicted adverse health effects in adults even in the absence of obesity in adulthood(30).

The intervention also led to an increase in aerobic fitness. This effect corresponds to a difference in running time of 20 seconds or a difference in the covered distance of 60 metres equivalent to an average increase of 5% from baseline, which is substantial considering the worldwide decline of youth fitness by 0.43% a year over the past two decades(31). Only one previous controlled intervention trial found improvements in body composition and in aerobic fitness(32). Additionally, our intervention resulted in an improved cardiovascular risk score that included all components of the metabolic syndrome. This reduction in cardiovascular risk was seen in all children in the intervention group, irrespective of their initial body mass index-z-scores. To our knowledge, this is the first school-based, long-term physical activity intervention that documents beneficial changes in all these parameters. Our study was a demanding 'real life' intervention trial, in which we successfully increased physical activity, thereby achieving multiple beneficial health effects. As not only obesity but also the presence of overt cardiovascular disease is seen in an increasing number of children(33), a shift of the population median by five to seven points in the favourable direction on the centile scale as documented in our intervention group for body fat and fitness and the cardiovascular risk score would be expected to have a considerable public health impact(34). Moreover, the observed effects at the group level were large enough to be relevant even at the individual level. Autopsy studies of children who had died in accidents or by homicide have shown that 50% of 2-15 year old children have fatty streaks in the coronary arteries, and all of them have fatty streaks in the aorta(35). As the extent of these lesions was related to body mass index, blood pressure, and blood lipids, an improvement in the cardiovascular risk score by a lifestyle intervention early in life focusing on several essential health outcomes may help to slow the occurrence of these atherosclerotic changes.

Strengths and limitations

This study contributes a practical way of successfully implementing a physical activity program in public schools to reduce the extensive health burden of childhood obesity. It shows that primary prevention in school by a multi-component physical activity curriculum including daily physical education based on a structured curriculum, short activity breaks, and physical activity homework, can improve aerobic fitness and decrease body fat and possibly cardiovascular risk. The favourable outcome of this pure physical activity intervention is even more encouraging considering the high participation rate and the use of precise methods. We used skinfold measurement to define the level of obesity in addition to the more imprecise measure of body mass index, and we assessed aerobic fitness, all important cardiovascular risk factors and physical activity by objective means. The success of this study, in contrast to other well-designed randomized controlled trials(13, 27), probably lies in the mandatory structure of the intervention by changing the school environment(36). Importantly, the children and teachers enjoyed the intervention, which guaranteed compliance, and it was sufficiently intense, of adequate duration(37), and included expert physical education teachers(38). On the basis of the accelerometer data, the in-school part of the intervention – that is, structuring of the existent three physical education lessons and adding two additional lessons and activity breaks – was almost entirely responsible for this difference. The level of adherence to the intervention outside school (physical activity homework) was insufficient, which is a limitation of this study. Nevertheless, the qualitatively and quantitatively improved physical education resulted in higher levels of total and moderate-vigorous physical activity in school as well as over the whole day, which was sufficient to improve aerobic fitness(39). This emphasises the importance of an increase in the amount and quality of physical education and activity at school, as many children do not seem to be responsive to educational programs aiming at increasing physical activity outside school(12). A behavioural change of the whole family is also very difficult to achieve, considering the excessive numbers of inactive and obese adults. Our estimate of the effect of the intervention on physical activity is based on 50% of the study population. This might have introduced some bias. What argues against this concern, however, is that we did not find relevant differences at baseline or follow-up between the sub-samples with and without physical activity measurements at both time points. Another limitation is that the schools were randomized before the baseline assessment, as the curriculum of the intervention classes had to be changed well in advance to accommodate two additional physical education lessons. However, baseline characteristics were similar between the groups, making a pre-intervention effect very unlikely.

Generalizibility and implications

The sampling frame included 10% of the population of two provinces of Switzerland and included rural and urban areas with a migrant population of 10-30%, which is representative for Switzerland. The population of Switzerland is considered to be representative for central Europe, so the results of this study may also apply to many Western countries. However, differences between school systems in different countries might affect the generalizibility of our findings, requiring specific research. Our program provided additional structured and compulsory activity for all children in a class and also included those who might have dropped out if given a free choice. Programs with compulsory physical activity components seem to be superior to those based on educational interventions(36), as adherence is guaranteed. Also, the inclusion of all children in a class avoids any stigmatization of overweight and unfit children and gives all children an equal chance to benefit from this type of intervention. The fact that 90% of all children and 70% of the teachers liked the program and wished that it would continue is also reassuring. The multi-component and systemic physical activity approach, which included a variety of strategies to enhance physical activity, may have reached more children by broadening the levels of the intervention and the spectrum of activities. All these components might encourage children to increase activity levels in the future by increasing joy, fitness, and motor skills that further enhance physical activity with the potential beneficial effects on body composition and cardiovascular risk. Although we know that our program was successful when applied over the period of one academic year, we do not know whether the effects could be sustained. Future research should include intervention programs over several years and long-term follow-up to define the ideal content, setting, and duration of preventive interventions, as well as assessment of costs to define the cost-effectiveness of such interventions.

CONCLUSIONS

A school-based, multi-component physical activity intervention including compulsory elements improved physical activity and fitness and reduced adiposity in children. Implementation of such a program may help to improve the health and fitness of children and also to improve health later in life by reducing cardiovascular and other diseases.

REFERENCES

(1) Kipping RR, Jago R, Lawlor DA. Obesity in Children. Part 1: Epidemiology, Measurement, Risk Factors, and Screening. Br Med J. 2008; 337: a1824.

(2) Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of Overweight and Obesity in the United States, 1999-2004. JAMA. 2006; 295(13): 1549.

(3) Weiss R, Dziura J, Burgert TS, Tamborlane WV, Taksali SE, Yeckel CW, et al. Obesity and the Metabolic Syndrome in Children and Adolescents. N Engl J Med. 2004; 350(23): 2362.

(4) Daniels SR, Arnett DK, Eckel RH, Gidding SS, Hayman LL, Kumanyika S, et al. Overweight in Children and Adolescents: Pathophysiology, Consequences, Prevention, and Treatment. Circulation. 2005; 111(15): 1999.

(5) Olshansky SJ, Passaro DJ, Hershow RC, Layden J, Carnes BA, Brody J, et al. A Potential Decline in Life Expectancy in the United States in the 21st Century. N Engl J Med. 2005; 352(11): 1138.

(6) Must A, Tybor DJ. Physical Activity and Sedentary Behavior: A Review of Longitudinal Studies of Weight and Adiposity in Youth. Int J Obes. 2005; 29 Suppl 2: S84.

(7) Hu FB, Willett WC, Li T, Stampfer MJ, Colditz GA, Manson JE. Adiposity as Compared with Physical Activity in Predicting Mortality among Women. N Engl J Med. 2004; 351(26): 2694.

(8) Andersen LB, Harro M, Sardinha LB, Froberg K, Ekelund U, Brage S, et al. Physical Activity and Clustered Cardiovascular Risk in Children: A Cross-Sectional Study (the European Youth Heart Study). Lancet. 2006; 368(9532): 299.

(9) Brage S, Wedderkopp N, Ekelund U, Franks PW, Wareham NJ, Andersen LB, et al. Features of the Metabolic Syndrome Are Associated with Objectively Measured Physical Activity and Fitness in Danish Children: The European Youth Heart Study (Eyhs). Diabetes Care. 2004; 27(9): 2141.

(10) Singh AS, Mulder C, Twisk JW, van Mechelen W, Chinapaw MJ. Tracking of Childhood Overweight into Adulthood: A Systematic Review of the Literature. Obes Rev. 2008; 9(5): 474.

(11) Bao W, Srinivasan SR, Wattigney WA, Berenson GS. Persistence of Multiple Cardiovascular Risk Clustering Related to Syndrome X from Childhood to Young Adulthood. The Bogalusa Heart Study. Arch Intern Med. 1994; 154(16): 1842.

(12) van Sluijs EM, McMinn AM, Griffin SJ. Effectiveness of Interventions to Promote Physical Activity in Children and Adolescents: Systematic Review of Controlled Trials. Br Med J. 2007; 335(7622): 703.

(13) Summerbell C, Waters E, Edmunds L, Kelly S, Brown T, Campbell K. Interventions for Preventing Obesity in Children. Cochrane Database Syst Rev. 2005; (3): CD001871.

(14) Kipping RR, Jago R, Lawlor DA. Obesity in Children. Part 2: Prevention and Management. Br Med J. 2008; 337: a1848.

(15) Zahner L, Puder JJ, Roth R, Schmid M, Guldimann R, Puhse U, et al. A School-Based Physical Activity Program to Improve Health and Fitness in Children Aged 6-13 Years ("Kinder-Sportstudie Kiss"): Study Design of a Randomized Controlled Trial [Isrctn15360785]. BMC Public Health. 2006; 6: 147.

(16) Egger G, Swinburn B. An "Ecological" Approach to the Obesity Pandemic. Br Med J. 1997; 315(7106): 477.

(17) Prader A, Largo RH, Molinari L, Issler C. Physical Growth of Swiss Children from Birth to 20 Years of Age. First Zurich Longitudinal Study of Growth and Development. Helv Peadiatr Acta Suppl. 1989; 52: 1.

(18) Lohman TG, Roche AF, Martorell R. Anthropometric Standardization Reference Material. Champaign: Human Kinetics; 1988.

(19) Leger LA, Mercier D, Gadoury C, Lambert J. The Multistage 20 Metre Shuttle Run Test for Aerobic Fitness. J Sports Sci. 1988; 6(2): 93.

(20) Freedson P, Pober D, Janz KF. Calibration of Accelerometer Output for Children. Med Sci Sports Exerc. 2005; 37(11 Suppl): S523.

(21) Moses S, Meyer U, Puder JJ, Roth R, Zahner L, Kriemler S. Das Bewegungsverhalten Von Primarschulkindern in Der Schweiz. Schweizerische Zeitschrift für «Sportmedizin und Sporttraumatologie». 2007; 55(2): 62.

(22) Landgraf JM, Maunsell E, Speechley KN, Bullinger M, Campbell S, Abetz L, et al. Canadian-French, German and Uk Versions of the Child Health Questionnaire: Methodology and Preliminary Item Scaling Results. Qual Life Res. 1998; 7(5): 433.

(23) National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents. Pediatrics. 2004; 114(2 Suppl 4th Report): 555.

(24) Eisenmann JC. On the Use of a Continuous Metabolic Syndrome Score in Pediatric Research. Cardiovasc Diabetol. 2008; 7: 17.

(25) Woringer V, Schutz Y. [Obesity in Switzerland: Body Mass Index (Bmi) Percentiles of a Child and Adolescent Population Born in 1980 in Lausanne and Comparison with Swiss Norms (1955)]. Soz Praventivmed. 2003; 48(2): 121.

(26) Fredriks AM, van Buuren S, Fekkes M, Verloove-Vanhorick SP, Wit JM. Are Age References for Waist Circumference, Hip Circumference and Waist-Hip Ratio in Dutch Children Useful in Clinical Practice? Eur J Pediatr. 2005; 164(4): 216.

(27) Kamath CC, Vickers KS, Ehrlich A, McGovern L, Johnson J, Singhal V, et al. Clinical Review: Behavioral Interventions to Prevent Childhood Obesity: A Systematic Review and Metaanalyses of Randomized Trials. J Clin Endocrinol Metab. 2008; 93(12): 4606.

(28) Robinson TN. Reducing Children's Television Viewing to Prevent Obesity: A Randomized Controlled Trial. JAMA. 1999; 282(16): 1561.

(29) Baker JL, Olsen LW, Sorensen TI. Childhood Body-Mass Index and the Risk of Coronary Heart Disease in Adulthood. N Engl J Med. 2007; 357(23): 2329.

(30) Must A, Jaques PF, Dallal GE, Bajema CJ, Dietz WH. Long-Term Morbidity and Mortality of Overweight Adolescents. A Follow up of the Harvard Growth Study of 1922-1935. N Engl J Med. 1992; 327: 1350.

(31) Tomkinson GR, Leger LA, Olds TS, Cazorla G. Secular Trends in the Performance of Children and Adolescents (1980-2000): An Analysis of 55 Studies of the 20m Shuttle Run Test in 11 Countries. Sports Med. 2003; 33(4): 285.

(32) Manios Y, Kafatos A, Mamalakis G. The Effects of a Health Education Intervention Initiated at First Grade over a 3 Year Period: Physical Activity and Fitness Indices. Health Educ Res. 1998; 13(4): 593.

(33) Freedman DS, Kahn HS, Mei Z, Grummer-Strawn LM, Dietz WH, Srinivasan SR, et al. Relation of Body Mass Index and Waist-to-Height Ratio to Cardiovascular Disease Risk Factors in Children and Adolescents: The Bogalusa Heart Study. Am J Clin Nutr. 2007; 86(1): 33.

(34) Rose G. Rose's Strategy of Preventive Medicine. 2nd ed: Oxford University Press; 2008.

(35) Berenson GS, Srinivasan SR, Bao W, Newman WP, 3rd, Tracy RE, Wattigney WA. Association between Multiple Cardiovascular Risk Factors and Atherosclerosis in Children and Young Adults. The Bogalusa Heart Study. N Engl J Med. 1998; 338(23): 1650.

(36) Connelly JB, Duaso MJ, Butler G. A Systematic Review of Controlled Trials of Interventions to Prevent Childhood Obesity and Overweight: A Realistic Synthesis of the Evidence. Public Health. 2007; 121(7): 510.

(37) Prochaska JO, Velicer WF. The Transtheoretical Model of Health Behavior Change. Am J Health Promot. 1997; 12(1): 38.

(38) McKenzie TL, Sallis JF, Kolody B, Faucette FN. Long-Term Effects of a Physical Education Curriculum and Staff Development Program: Spark. Res Q Exerc Sport. 1997; 68(4): 280.

(39) Luepker RV, Perry CL, McKinlay SM, Nader PR, Parcel GS, Stone EJ, et al. Outcomes of a Field Trial to Improve Children's Dietary Patterns and Physical Activity. The Child and Adolescent Trial for Cardiovascular Health. Catch Collaborative Group. JAMA. 1996; 275(10): 768.

CHAPTER 7

Long-term effect of a school-based physical activity program (KISS) on fitness and adiposity in primary school children: a cluster-randomized controlled trial

Ursina Meyer
Christian Schindler
Lukas Zahner
Dominque Ernst
Nicole Probst-Hensch
Helge Hebestreit
Jardena J. Puder
Susi Kriemler

in submission

LONG-TERM EFFECT OF A SCHOOL-BASED PHYSICAL ACTIVITY PROGRAM (KISS) ON FITNESS AND ADIPOSITY IN PRIMARY SCHOOL CHILDREN: A CLUSTER-RANDOMIZED CONTROLLED TRIAL

ABSTRACT

Objective To assess the long-term effects three years after the end of a successful school-based physical activity program of one school-year with beneficial effects on body fat, aerobic fitness and physical activity. **Design** Cluster randomized controlled school-based intervention trial from August 2005 to June 2006 with a follow-up in 2009. **Setting** Twenty eight classes from 15 elementary schools in Switzerland randomly selected and assigned in a ratio 4:3 by an externally hosted computer-based random-number table to an intervention (n=16) or a control arm (n=12) after stratification for grade (1st and 5th grade). **Participants** Of 502 children that consented at baseline, 312 (62%) completed the follow-up with 296 (59%) having a full data set, mean age at follow-up 10.6 years (SD 0.3) for 1st graders, 15.0 years (0.5) for 5th graders. Children in the intervention arm (n=297) received a multi-component physical activity program that included structuring the three existing and adding two additional physical education lessons per week, daily short activity breaks and physical activity homework. Children (n=205) and parents in the control group were not informed of an intervention group. After the end of the intervention no further inputs were given. **Main outcome measures** Primary outcome measures included body fat (sum of four skinfolds), aerobic fitness (shuttle run test), physical activity (accelerometry), and quality of life (questionnaires). Secondary outcome measures included BMI and a cardiovascular risk score. For most outcomes, the assessors were blinded. **Results** After adjustment for grade, gender, baseline values and clustering within classes, children in the intervention arm compared with controls showed persistent increases in aerobic fitness (0.373 z-score units [0.157 to 0.59, p=0.001]) corresponding to a 15% difference of change between baseline and follow-up, while the other beneficial effects on primary and secondary outcomes did not persist. **Conclusions** Although this school-based multi-component physical activity intervention induced persistent beneficial long-term effects on aerobic fitness, a continuous intervention seems necessary to maintain overall beneficial health effects as reached while intervening.

INTRODUCTION

In view of the dramatic increase in excessive body weight among youth during the last decades, more and more children will be at risk of having cardiovascular disease in adulthood[1, 2]. The individual burden is huge and affects physiological and psychological well-being in many respects[3]. The extent will be so high that life expectancy may be shortened by several years by the mid of this century – an effect comparable to all cancers combined[4]. As most paediatric obesity treatment interventions are marked by small changes in relative body weight or adiposity[5], a substantial relapse rate and despite treatment a strong tracking into adulthood[6], the importance of primary prevention has become indisputable[7].

Physical inactivity has become the fourth leading cause of mortality worldwide and both, physical inactivity and low aerobic fitness are associated with a high burden of chronic disease[8]. In children, physical inactivity and lack of fitness are associated with increasing prevalence of cardiovascular risk factors in children[9-11], even independent of body weight[12]. There is even evidence that aerobic fitness protects individuals with increased body fat from an increased mortality[13].

School-based intervention studies promoting a healthy lifestyle have shown increasingly positive results[14, 15], but there is a striking paucity of long-term follow-ups[14] especially of high-quality trials implementing theory driven randomized controlled trials in youth that had shown efficacy at the end of the intervention.

We performed a successful cluster-randomized controlled trial with a school-based stringent physical activity program vs. traditional physical education during one school-year with beneficial effects on aerobic fitness, physical activity, body fat and a composite cardiovascular risk factor score in the intervention as compared to the control group[16]. We here report findings of the 3-year-follow-up. No further steps were taken after the intervention had stopped except for an individual report of individual findings provided to the children and parents, and a summary report to the teachers that was sent out in 2007.

METHODS

Design and study population

The design and main result paper can be found elsewhere[16, 17]. Briefly, the study was performed between August 2005 and July 2006 in two (Aargau, Baselland) of the 26 provinces of Switzerland comprising about 10% of the Swiss population. Twenty-eight out of 190 consenting classes were selected based on a computer-generated random-number table which was in the hands of a person not involved in the study. Participating schools fulfilled our eligibility criteria, i.e. rural or urban localisation, a prevalence of 10-30% migrants as in the Swiss population and, for practical reasons, the presence of at least a first- and fifth-grade class per school. A careful continuous update of the address list enabled us to recontact participants by the school and individually.

Intervention

The intervention was targeted both at the cluster and the individual level and was based on a socio-ecological conceptual model[18] focusing on increasing daily physical activity as described previously[17]. Briefly, children in both groups had three physical education lessons per week, which are compulsory by law. The intervention group had two additional physical education lessons on the remaining school days. All five physical education lessons for the children in the intervention group were prepared by a team of expert physical education teachers. The same curriculum was provided to all intervention classes. While the three compulsory weekly physical education lessons (45 minutes each) were given by the usual classroom teachers according to the specified curriculum, the two additional weekly lessons (45 minutes each) were taught mostly outdoors by physical education teachers. In addition, three to five short activity breaks (two to five minutes each) during academic lessons, comprising motor skill tasks such as jumping or balancing on one leg, power games or coordinative tasks were introduced every day. The children received daily physical activity homework of about 10 minutes duration prepared by the physical education teachers including aerobic, strength or motor skill tasks like tooth brushing while standing on one leg, hopping up and down the stairs, rope jumping or comparable activities. Children and parents of the control group were not informed about the existence of the intervention program in other schools. The teachers in the control group knew about the intervention arm, but were not informed about its content.

Outcome measures

Baseline (August 2005) and post-intervention (June 2006) measurements were done at school within the same three week period for all children, with the intervention period lasting 9 months. The follow-up measurements were also done at school. Contacts were taken with the younger age group that were still in the same classes through the schools and with the older children that were all in different classes (secondary school) by individual contacts through our address list that was constantly and carefully updated. The younger children now in fifth grade were tested in June 2009 in the respective schools. Testing of the former fifth graders now attending different secondary schools, but usually still in the area of their homes, was performed from August to November 2009 in a school that was easily reachable for the adolescents. All testing was done during active school time and children received a gift cheque of their choice for 30 CHF (smaller children) or 50 CHF (older children).

Measurement procedures have been described previously(16, 17). All measures were taken at baseline, post-intervention and at follow-up exactly the same way. Blinding of the assessors at follow-up was fulfilled except again for waist circumference and skinfold assessment that was measured by the same persons as before. Primary outcome measures included the sum of four skinfolds, aerobic fitness, physical activity and quality of life. Secondary outcome measures included body mass index (BMI) and a cardiovascular risk score comprising all variables of the metabolic syndrome.

The percentage of overweight children was calculated based on WHO criteria(19). Skinfold thickness was measured in triplicate to the nearest 0.5 mm with Harpenden calipers (HSK-BI, British Indicators, UK). The sum of four sites (triceps, biceps, subscapular and suprailiacal) was calculated[20]. Aerobic fitness was determined using the 20m shuttle run test as previously described[21]. Physical activity was monitored by an accelerometer (MTI/CSA 7164, Actigraph, Shalimar, FL, USA) which was worn continuously around the hip for 7 weekdays during each measure period. The sampling epoch was set to one minute. Time periods with over 15 minutes of continuous zero values were omitted. An individual child's physical activity data were included if at least three weekdays of measurements with a minimum of 12 hours and one weekend day of at least 10 hours were recorded[22]. Physical activity was expressed as average counts/min (cpm) and moderate-vigorous physical activity as minutes above 2000 cpm (which is equivalent to walking at about 4 km/h). Quality of life was assessed by the child health questionnaire[23] distributed at school in coded envelopes and completed by the child, if necessary, with the help of the parents. Blood pressure was measured at the right arm five times after a resting period of five minutes using an automated oscillograph (Oscillomate, CAS Medical Systems, Branford, CT, USA). The mean of the three measurements with the smallest variation was taken and then z-transformed[24]. Blood was drawn in the morning while fasting for measurements of glucose, insulin, and lipids as previously described[17] and a composite cardiovascular risk score[25] was computed by averaging the z-scores of all components of the metabolic syndrome (waist circumference, blood pressure (mean of systolic and diastolic blood pressure z-score), glucose, inverted HDL cholesterol, and triglycerides). Skewed data were log-transformed. Z-scores were derived from published age- and gender-specific norm values for BMI[19] and blood pressure[24]. The remaining variables were z-transformed using grade- and gender-specific means and standard deviations derived from the whole sample at each measurement period.

Statistical analysis

Statistical analyses were based on the intention-to-treat principle and results are reported at the level of individuals. Baseline measurements of the two groups were compared using a regression model with adjustment for cluster. Since the study population consisted of two distinct age groups, all analyses estimating intervention effects on outcomes were done using z-scores based on grade and gender. We used mixed linear models with z-scores at follow-up as dependent variables, group, gender and grade as fixed factors, school class as random effect, and the respective baseline z-score as covariate. School class was the smallest cluster in the sampling design and was therefore taken as a random effect. We did not add a second cluster adjustment for the new class of the older age group since the pupils were spread into multiple new classes with only a few remaining together. We nevertheless calculated the intraclass correlation coefficient (ICC) to compare the variation between school classes as a fraction of the total variance. We did not include pubertal stage according to Tanner stage, migrant or socio-economic status as covariates since their addition to the model did not change the results. For each outcome measure, the size of the intervention effect is reported as difference in its average z-scores at follow-up between the intervention and control group after adjustment for grade, gender, baseline values and clustering within school classes. Secondary analyses were performed by testing interactions of the intervention with gender, grade, and/or baseline BMI, categorised into two groups above and below the median(19). The sample size calculation has been described previously(16). Of note, 360 children were needed at the actual follow-up assessment based on the initial power calculation.

RESULTS

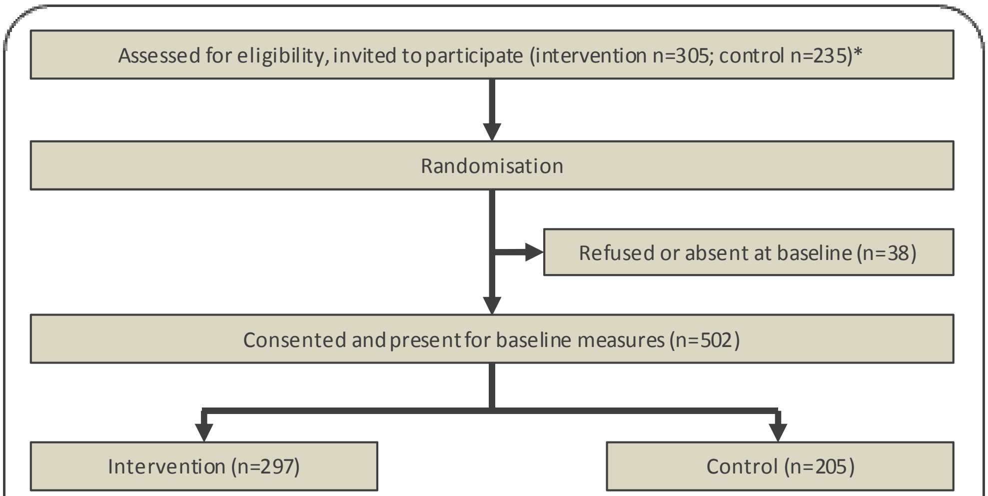
Twenty-eight classes in 15 schools totalling 502 children entered the study. Figure 7.1 provides sample size information throughout the trial. Table 7.1 shows baseline characteristics stratified by allocation arm and participation in the follow-up, and Table 7.2 describes results of the primary and secondary outcomes at baseline and follow-up, as well as the adjusted differences of change at follow-up.

First graders were 6.9±0.3 years at baseline and 10.6±0.3 years at follow-up, while fifth graders were 11.2±0.5 years at baseline and 15.0±0.5 years at follow-up. Overall participation was 62% of the original baseline sample. Participation rates were not different among the younger and older age group, but non-participation was much more common for the older age group, irrespective of group (78% of the intervention group and 66% of the control group of non-participants were from the older age category).

To make data more meaningful values are reported as raw data according to participation, but comparisons were done with z-scores. There were no major differences in baseline characteristics between participants and non-participants at follow-up, except for sum of four skinfolds, BMI and waist circumference which were lower in participants than in non-participants. Yet, the only significant group*participation interaction existed for BMI, i.e. with lower values for participants of the intervention compared to participants of the control group. Of note, no group*participation interaction was apparent for the sum of four skinfolds or waist circumference.

Primary and secondary outcomes

The results of the primary and secondary outcomes are presented in Table 7.2. Compared to controls, children in the intervention group showed a significant higher aerobic fitness in the shuttle run by 0.373 z-score units (95% CI 0.157 to 0.59), corresponding to a shift from the 50th to the 65th percentile or a difference in change of 15%. This effect corresponds to an average difference of improved running distance of about 150 m at the highest speed reached during the test between the two groups. Children of the intervention continued to increase their fitness from post-intervention to the follow-up while controls lost performance predominantly after the intervention had finished (Figure 7.2). Children from the intervention showed a trend towards higher levels of physical activity. Intervention effects on primary outcomes were comparable in children with and without complete physical activity data (all p>0.4). The remaining primary and secondary outcome variables were not significantly different among groups. This was also true for the variables that showed beneficial effects in favour of the intervention at the end of the intervention period, including sum of four skinfolds, physical activity and the cardiovascular risk score.



Intervention Base-line	Intervention Follow up	Intervention Both		Control Base-line	Control Follow up	Control Both
			Primary outcomes			
296	198	194	Skinfolds	201	114	102
297	187	181	Fitness	205	107	100
227	126	89	Physical activity	164	69	56
286	154	136	Quality of life	170	79	55
			Secondary outcomes			
249	159	145	Cardiovascular risk score	117	73	53
296	198	194	Body mass index	201	114	102
294	198	193	Blood pressure	201	113	101
291	196	189	Waist circumference	201	114	102

Figure 7.1 Flow of individual participants through study, with outcome measures.

Table 7.1 Baseline characteristics of 502 elementary schoolchildren according to treatment arm and participation at follow-up. Values are means (standard deviation) unless stated otherwise.

	Participants				Non-Participants						
	INT		CON		INT		CON		Baseline Differences*		
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	P_{part}	P_{group}	$P_{group*part}$
Age (years)	189	8.6 (2.0)	100	8.4 (2.1)	108	10.2 (1.8)	105	9.8 (2.2)	0.071	0.289	0.634
Height (cm)	189	132 (13)	100	131 (13)	101	141 (10)	93	140 (13)	0.619	0.994	0.335
Weight (kg)	189	29.9 (8.3)	100	28.5 (8.7)	101	36.0 (9.4)	93	36.0 (10.3)	0.023	0.389	0.331
Gender, %girls		99 (52%)		59 (59%)		54 (50%)		46 (44%)	0.037	0.466	0.218
1st Grade (%)		108 (57%)		65 (65%)		24 (22%)		36 (34%)	0.000	0.052	0.500
Overweight (%)		42 (22%)		14 (14%)		23 (23%)		31 (33%)	0.002	0.103	0.020
Prepubertal (%)		152 (80%)		85 (85%)		60 (58%)		69 (67%)	0.215	0.976	0.676
Migrants (%)		50 (26%)		21 (21%)		35 (32%)		35 (33%)	0.006	0.553	0.130
Low parental education (%)		11 (6%)		5 (5%)		20 (21%)		10 (11%)	0.198	0.089	0.305
Sum of 4 skinfolds (mm)[b,d]	187	30.71 (11.28)	100	27.96 (10.59)	99	34.89 (16.20)	93	35.15 (13.84)	0.002	0.546	0.114
Aerobic fitness [b]	181	5.32 (2.34)	100	5.38 (1.92)	116	6.16 (2.04)	105	6.22 (2.1)	0.114	0.179	0.981
TPA (cpm)	87	729.78 (176.35)	56	795.59 (164.17)	134	720.31 (227.43)	96	721.69 (228.49)	0.798	0.702	0.940
MVPA (min/day)	87	89.84 (28.01)	56	98.91 (28.05)	134	90.85 (36.60)	96	88.34 (35.14)	0.508	0.697	0.667
QoL – physical	81	54.59 (5.24)	41	55.16 (5.06)	170	53.49 (9.04)	107	52.45 (8.60)	0.821	0.909	0.427
QoL –psychological	81	53.60 (6.66)	41	54.43 (4.88)	170	52.46 (6.87)	107	52.22 (7.32)	0.509	0.743	0.806
BMI [a]	189	16.84 (2.16)	100	16.12 (2.12)	101	17.74 (3.27)	93	17.97 (2.73)	0.000	0.290	0.006
Cardiovascular risk score	139	-0.04 (0.44)	52	0.02 (0.55)	104	0.03 (0.51)	63	0.06 (0.44)	0.489	0.517	0.860
Waist circumference[b]	186	56.79 (6.08)	100	55.40 (5.44)	99	60.36 (7.91)	93	60.11 (6.40)	0.042	0.947	0.452
Systolic blood pressure[c]	188	102.85 (8.80)	100	101.12 (7.86)	100	105.81 (8.07)	93	104.13 (7.67)	0.247	0.365	0.822
Diastolic blood pressure[c]	188	60.99 (7.57)	100	60.55 (7.26)	100	64.46 (7.56)	93	62.14 (6.98)	0.568	0.102	0.235
Glucose [b]	135	4.52 (0.39)	46	4.55 (0.48)	99	4.63 (0.41)	57	4.63 (0.39)	0.991	0.856	0.662
HDL cholesterol[b,d]	139	1.63 (0.34)	52	1.61 (0.34)	104	1.68 (0.34)	63	1.62 (0.34)	0.918	0.450	0.755
Triglycerides[b,d]	135	0.57 (0.22)	48	0.62 (0.31)	101	0.6 (0.27)	57	0.64 (0.31)	0.844	0.428	0.884

*Regression or logistic regression analyses were done based on age-group and gender based z-scores to compare data for group, participation and group*participation differences after adjustment for cluster (class).
TPA=total physical activity; cpm=counts per minute; MVPA=moderate and vigorous physical activity
based on [a] who-, [b]internal, [c]CDC zscores [d] ln-transformed

The intraclass correlation coefficients were ≤0.1 indicating a low level of clustering within school classes. An additional adjustment of all primary outcome analyses for the random effect of "school" did not explain any further variance. Secondary analyses that involved the study of potential effect modifications by gender, grade, or baseline BMI (being dichotomised at the median) did not show any significant result. Factors such as sport club or leisure-time sports participation, parents' support for, or attitude towards physical activity did not explain group differences.

Table 7.2 Outcome measures of the three year follow-up in children according to physical activity intervention aimed at increasing physical activity, fitness and at reducing body fat and a cardiovascular risk score. Values at baseline and follow-up are means (SD)

	INT		CON		Adjusted difference at follow-up**			
Variables	Baseline	Follow-up	Baseline	Follow-up	n	Coefficient (95% CI)	p value	ICC
Sum of 4 skinfolds [b,d]	30.71 (11.28)	42.07 (19.25)	27.96 (10.59)	39.72 (22.3)	293	-0.076 (-0.223 - 0.070)	0.307	<0.01
Aerobic fitness [b]	5.32 (2.34)	6.83 (2.16)	5.38 (1.92)	6.2 (2.11)	281	0.373 (0.157 - 0.590)	0.001	0.02
TPA (cpm)	730 (176)	544 (208)	796 (164)	569 (201)	145	0.320 (-0.012 - 0.651)	0.059	0.02
MVPA (min/d)	89.8 (28.0)	61.5 (28.1)	98.9 (28.1)	66.9 (32.5)	145	0.143 (-0.204 - 0.490)	0.420	<0.01
QoL – physical	54.59 (5.24)	53.84 (7.33)	55.16 (5.06)	52.47 (7.01)	191	0.910 (-1.476 - 3.296)	0.455	0.03
QoL – psychological	53.60 (6.66)	53.02 (6.78)	54.43 (4.88)	51.73 (9.58)	191	1.424 (-0.661 - 3.509)	0.181	<0.01
BMI [a]	16.84 (2.16)	19.08 (2.82)	16.12 (2.12)	18.17 (3.35)	296	0.010 (-0.130 - 0.151)	0.884	<0.01
Cardiovascular risk score	-0.04 (0.44)	0.01 (0.51)	0.02 (0.55)	0.00 (0.55)	291	-0.051 (-0.195 - 0.092)	0.482	<0.01
Waist circumference[b]	56.79 (6.08)	64.69 (7.32)	55.40 (5.44)	63.3 (7.87)	198	-0.003 (-0.208 - 0.201)	0.975	0.2
Systolic blood pressure[c]	102.8 (8.8)	110.1 (10.8)	101.1 (7.9)	105.3 (9.6)	294	0.279 (-0.001 - 0.559)	0.051	0.1
Diastolic blood pressure[c]	60.99 (7.57)	67 (7.95)	60.55 (7.26)	64.43 (7.93)	294	0.146 (-0.054 - 0.347)	0.152	0.1
Glucose [b]	4.52 (0.39)	4.75 (0.43)	4.55 (0.48)	4.73 (0.56)	187	-0.004 (-0.401 - 0.394)	0.986	0.1
HDL cholesterol [b,d]	1.63 (0.34)	1.49 (0.34)	1.61 (0.34)	1.44 (0.38)	198	0.147 (-0.155 - 0.449)	0.339	0.06
Triglycerides [b,d]	0.57 (0.22)	0.8 (0.36)	0.62 (0.31)	0.77 (0.36)	190	0.143 (-0.265 - 0.550)	0.492	0.1

**Differences in average change and 95% confidence intervals (CI) are the differences between intervention and controls after adjustment by mixed-model regression analysis for grade, gender and cluster (class).
TPA=total physical activity; cpm=counts per minute; MVPA=moderate and vigorous physical activity
based on [a] who-, [b]internal, [c]CDC zscores
[d] ln-transformed

DISCUSSION

Potential health benefits of prevention in childhood overweight and physical inactivity are of paramount Public Health importance because of multiple associated global physiological and psychological health problems and the enormous difficulty of effective treatment. This randomized controlled trial showed that a multi-component physical activity intervention of one school-year in first and fifth grade school children favourably affected body composition, aerobic fitness, physical activity and cardiovascular risk. At the 3-years follow-up, aerobic fitness remained significantly higher in favour of the intervention group, but all other reported beneficial effects did not persist.

The most important finding of the follow-up was that our intervention of one academic year that led to increased aerobic fitness at the end of the intervention, showed a further increase in favour of the intervention group during the three years that followed. It means that during each minute that the children ran forth and back in the gyms, children from the intervention group covered about one length of 20 m more per minute than the controls equivalent to a difference in change of 15%. The change in difference increased even more than right after the intervention due to both an increase in fitness in the intervention group and a reduction of fitness in the control group. The decrease in the control group corresponded well to the internationally reported decline of youth fitness by 0.43% per year over the last two decades(26). There are no other studies that documented long-term effects of lifestyle interventions on fitness except a few studies with very low follow-up participation rates that lost beneficial effects 4(27) and 22(28) years after an intervention. It is possible that part of the maintained effect may be related to an increased quality and quantity of the physical education, or some behavioral change in the children themselves based on their positive experience of the intervention itself. This positive attitude is underlined by 70% of the teachers and 90% of the children that wanted daily physical education to continue after the intervention had stopped(16). Explanatory factors such as sport club or leisure-time sport participation or parents' attitude towards and support for physical activity did not help explaining the difference in aerobic fitness.

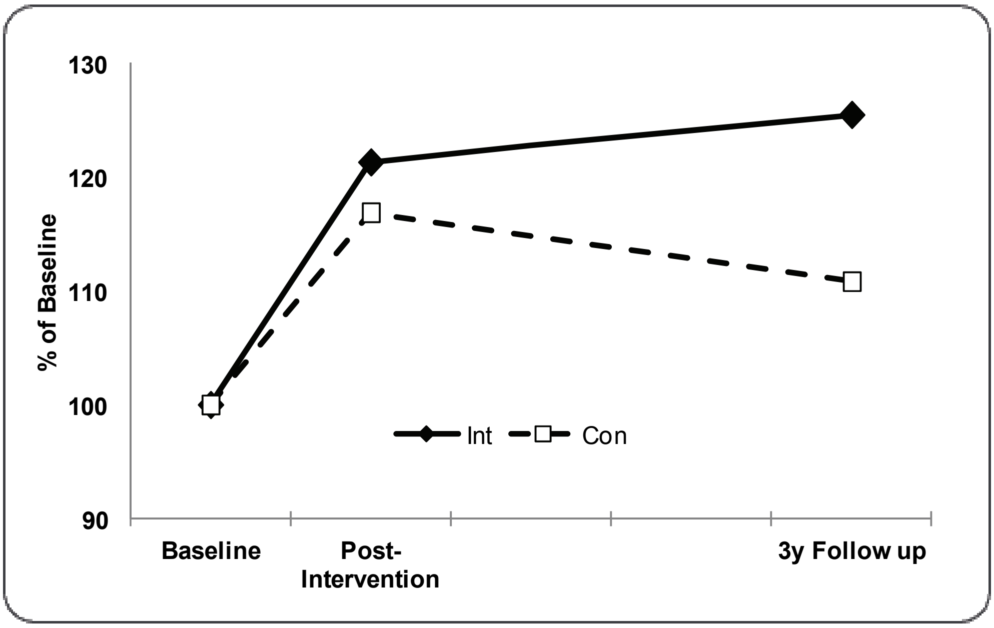


Figure 7.2 Pattern of aerobic fitness change by group.

Children's physical activity levels at the follow-up were not different among groups, although there was a trend that pointed towards the right direction, i.e., higher levels in children from the intervention compared to controls. This is in contrast to other long-term follow-ups in which leisure time physical activity was still increased three to 12 years after the intervention(29-31). It is possible that these questionnaire based assessments may have been hampered by factors such as social desirability, reporting or selection bias as most of these programs did not show persistent effects on aerobic fitness(32). The lack of significant physical activity results in our study could also have occurred due to insufficient power due to a considerable dropout and non-compliance to wear the accelerometer even in case of attendance of the follow-up.

Our intervention resulted in an improved body composition with less body fat and cardiovascular risk score that included all components of the metabolic syndrome. This reduction in the cardiovascular risk was seen in all children of the intervention group irrespective of initial BMI z-scores. Unfortunately, this effect was not any more present at follow-up. Only one controlled study with a similar follow-up duration and after a six year intervention period had reported persistent beneficial effects on blood lipids and blood pressure(32, 33), while most studies irrespective of methodological quality or duration of the follow-up lost their beneficial effects on adiposity or cardiovascular risk factors(28, 31). As one has to be careful by interpreting these data based on methodological limitations and high dropout rates in all of these studies, the maintenance of intervention program seem necessary over longer time spans, preferably over the whole school period, to have persisting beneficial health effects.

Strengths and limitations

This study contributes important findings regarding long-term effects of a physical activity program in public school urgently needed to increase or maintain health in children. It shows that primary prevention in school by a multi-component physical activity curriculum including daily physical education based on a structured curriculum, short activity breaks and physical activity homework, can improve aerobic fitness and decrease body fat and possibly cardiovascular risk on a short term basis, but that effects except for aerobic fitness do not persist once the intervention is stopped. It is, however, encouraging that aerobic fitness as one of the most important cardiovascular protection factor for children(9, 11) as well as adults(34) even increased after the end of the intervention. The public health importance is underlined by evidence that aerobic fitness seems to be even more important than percent body fat in determining mortality(13). From a behavioral perspective, teaching the children to be more active by allowing and supporting them to move, may be more motivating than “forbidding” them to eat things or amounts of food they like.

In accordance to every single published long-term follow-up of school-based intervention studies published so far, the most important limitation of the current study is the considerable dropout rate despite the fact that participants and non-participants were not different for baseline characteristics. The level of dropout is comparable to timely comparable, but still much better than long-term follow-ups of extended time windows. There is no question that we did everything to maximizing participation; multiple test dates were offered, testing windows were set during official school time, multiple attempts of motivational inputs were given by teachers and the KISS staff, and finally gift cheques of the children’s choice (books, clothes, sport gear, music, jewellery) with the value of 25 and 40 Euros for the younger and older children, respectively were provided. Still, these consistent high dropout rates have to be considered in the initial power analyses especially when adolescents with their “wilful” attitudes are involved.

Generalizibility and implications

The original sampling included 10% of the population out of two provinces of Switzerland and included rural and urban areas with a migrant population of 10-30% which is somehow representative for Switzerland and also for central Europe. Still, differences between school systems in different countries might have an impact on findings, requiring specific research.

The fact that multiple beneficial effects of the intervention were lost is another indirect evidence that the mandatory structure of the intervention by changing the school environment was crucial for the success[35]. Our promising and effective public health strategy of environmental change was nothing else than "ruining the moving stairs that are running beside a simple stairway, not leaving any choice to the children who were forced to walk up the stairs". The fact that 90% of all children and 70% of the teachers liked the program and wished that it would continue perfectly fulfils the precondition that they would accept the "destruction of the moving stairs" if they were replaced by "fun stairways". The principle of an intervention on the social system level, which is in this case the school itself, allows inclusion of all children of a school thereby avoiding unnecessary dropout of those who need it most and preventing any stigmatisation of overweight and unfit children thereby giving all children an equal chance to benefit from this type of intervention irrespective of their social or migrant origin.

Conclusions

In conclusion, a school-based multi-component physical activity intervention including compulsory elements improved physical activity and fitness and reduced adiposity in children after one academic year. Although this persisting improvement of aerobic fitness is most important and highly relevant from a public health perspective, cardiovascular benefits beside aerobic fitness did not persist three years after the end of the intervention. Longer term interventions throughout the school years seem to be needed to attain persistent overall beneficial health effects.

REFERENCES

(1) Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. The Relation of Overweight to Cardiovascular Risk Factors among Children and Adolescents: The Bogalusa Heart Study. Pediatrics. 1999; 103(6 Pt 1): 1175.

(2) Baker JL, Olsen LW, Sorensen TI. Childhood Body-Mass Index and the Risk of Coronary Heart Disease in Adulthood. N Engl J Med. 2007; 357(23): 2329.

(3) Kipping RR, Jago R, Lawlor DA. Obesity in Children. Part 1: Epidemiology, Measurement, Risk Factors, and Screening. Br Med J. 2008; 337: a1824.

(4) Olshansky SJ, Passaro DJ, Hershow RC, Layden J, Carnes BA, Brody J, et al. A Potential Decline in Life Expectancy in the United States in the 21st Century. N Engl J Med. 2005; 352(11): 1138.

(5) Oude Luttikhuis H, Baur L, Jansen H, Shrewsbury VA, O'Malley C, Stolk RP, et al. Interventions for Treating Obesity in Children. Cochrane Database Syst Rev. 2009; (1): CD001872.

(6) Singh AS, Mulder C, Twisk JW, van Mechelen W, Chinapaw MJ. Tracking of Childhood Overweight into Adulthood: A Systematic Review of the Literature. Obes Rev. 2008; (Mar 05 (Epub ahead of print)).

(7) van Sluijs EM, McMinn A. Preventing Obesity in Primary Schoolchildren. Br Med J. 2010; 340: c819.

(8) Beaglehole R, Bonita R, Horton R, Adams C, Alleyne G, Asaria P, et al. Priority Actions for the Non-Communicable Disease Crisis. Lancet. 2011; 377(9775): 1438.

(9) Andersen LB, Harro M, Sardinha LB, Froberg K, Ekelund U, Brage S, et al. Physical Activity and Clustered Cardiovascular Risk in Children: A Cross-Sectional Study (the European Youth Heart Study). Lancet. 2006; 368(9532): 299.

(10) Weiss R, Dziura J, Burgert TS, Tamborlane WV, Taksali SE, Yeckel CW, et al. Obesity and the Metabolic Syndrome in Children and Adolescents. N Engl J Med. 2004; 350(23): 2362.

(11) Andersen LB, Riddoch C, Kriemler S, Hills A. Physical Activity and Cardiovascular Risk Factors in Children. Br J Sports Med. 2011; 45(11): 871.

(12) Brage S, Wedderkopp N, Ekelund U, Franks PW, Wareham NJ, Andersen LB, et al. Features of the Metabolic Syndrome Are Associated with Objectively Measured Physical Activity and Fitness in Danish Children: The European Youth Heart Study (Eyhs). Diabetes Care. 2004; 27(9): 2141.

(13) Lee CD, Blair SN, Jackson AS. Cardiorespiratory Fitness, Body Composition, and All-Cause and Cardiovascular Disease Mortality in Men. Am J Clin Nutr. 1999; 69(3): 373.

(14) Dobbins M, De Corby K, Robeson P, Husson H, Tirilis D. School-Based Physical Activity Programs for Promoting Physical Activity and Fitness in Children and Adolescents Aged 6-18. Cochrane Database Syst Rev. 2009; (1): Cd007651.

(15) Kriemler S, Meyer U, Martin E, van Sluijs EM, Andersen LB, Martin BW. Effect of School-Based Interventions on Physical Activity and Fitness in Children and Adolescents: A Review of Reviews and Systematic Update. Br J Sports Med. 2011; 45(11): 923.

(16) Kriemler S, Zahner L, Schindler C, Meyer U, Hartmann T, Hebestreit H, et al. Effect of School Based Physical Activity Programme (Kiss) on Fitness and Adiposity in Primary Schoolchildren: Cluster Randomised Controlled Trial. Br Med J. 2010; 340(feb23 1): c785.

(17) Zahner L, Puder JJ, Roth R, Schmid M, Guldimann R, Puhse U, et al. A School-Based Physical Activity Program to Improve Health and Fitness in Children Aged 6-13 Years ("Kinder-Sportstudie Kiss"): Study Design of a Randomized Controlled Trial [Isrctn15360785]. BMC Public Health. 2006; 6: 147.

(18) Egger G, Swinburn B. An "Ecological" Approach to the Obesity Pandemic. Br Med J. 1997; 315(7106): 477.

(19) de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a Who Growth Reference for School-Aged Children and Adolescents. Bull World Health Organ. 2007; 85(9): 660.

(20) Lohman TG, Roche AF, Martorell R. Anthropometric Standardization Reference Material. Champaign: Human Kinetics Books; 1988.

(21) Leger LA, Mercier D, Gadoury C, Lambert J. The Multistage 20 Metre Shuttle Run Test for Aerobic Fitness. J Sports Sci. 1988; 6(2): 93.

(22) Freedson P, Pober D, Janz KF. Calibration of Accelerometer Output for Children. Med Sci Sports Exerc. 2005; 37(11 Suppl): S523.

(23) Landgraf JM, Maunsell E, Speechley KN, Bullinger M, Campbell S, Abetz L, et al. Canadian-French, German and Uk Versions of the Child Health Questionnaire: Methodology and Preliminary Item Scaling Results. Qual Life Res. 1998; 7(5): 433.

(24) Bloodpressure. The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents. Pediatrics. 2004; 114(2 Suppl 4th Report): 555.

(25) Eisenmann JC. On the Use of a Continuous Metabolic Syndrome Score in Pediatric Research. Cardiovasc Diabetol. 2008; 7: 17.

(26) Tomkinson GR, Leger LA, Olds TS, Cazorla G. Secular Trends in the Performance of Children and Adolescents (1980-2000): An Analysis of 55 Studies of the 20m Shuttle Run Test in 11 Countries. Sports Med. 2003; 33(4): 285.

(27) Manios Y, Kafatos I, Kafatos A. Ten-Year Follow-up of the Cretan Health and Nutrition Education Program on Children's Physical Activity Levels. Prev Med. 2006; 43(6): 442.

(28) Trudeau F, Laurencelle L, Tremblay J, Rajic M, Shephard RJ. A Long-Term Follow-up of Participants in the Trois-Riviäres Semi-Longitudinal Study of Growth and Development. Pediatr Exerc Sci. 1998; 10 366.

(29) Klepp KI, Tell GS, Vellar OD. Ten-Year Follow-up of the Oslo Youth Study Smoking Prevention Program. Prev Med. 1993; 22(4): 453.

(30) Kelder SH, Mitchell PD, McKenzie TL, Derby C, Strikmiller PK, Luepker RV, et al. Long-Term Implementation of the Catch Physical Education Program. Health Educ Behav. 2003; 30(4): 463.

(31) Nader PR, Stone EJ, Lytle LA, Perry CL, Osganian SK, Kelder S, et al. Three-Year Maintenance of Improved Diet and Physical Activity: The Catch Cohort. Child and Adolescent Trial for Cardiovascular Health. Arch Pediatr Adolesc Med. 1999; 153(7): 695.

(32) Manios Y, Kafatos A. Health and Nutrition Education in Primary Schools in Crete: 10 Years Follow-up of Serum Lipids, Physical Activity and Macronutrient Intake. Br J Nutr. 2006; 95(3): 568.

(33) Kafatos I, Manios Y, Moschandreas J, Kafatos A. Health and Nutrition Education Program in Primary Schools of Crete: Changes in Blood Pressure over 10 Years. Eur J Clin Nutr. 2007; 61(7): 837.

(34) Dwyer T, Magnussen CG, Schmidt MD, Ukoumunne OC, Ponsonby AL, Raitakari OT, et al. Decline in Physical Fitness from Childhood to Adulthood Associated with Increased Obesity and Insulin Resistance in Adults. Diabetes Care. 2009; 32(4): 683.

(35) Connelly JB, Duaso MJ, Butler G. A Systematic Review of Controlled Trials of Interventions to Prevent Childhood Obesity and Overweight: A Realistic Synthesis of the Evidence. Public Health. 2007; 121(7): 510.

CHAPTER 8

Effect of a general school-based physical activity intervention on bone mineral content and density: A cluster-randomized controlled trial

Ursina Meyer
Michael Romann
Lukas Zahner
Christian Schindler
Jardena J. Puder
Marius Kraenzlin
Rene Rizzoli
Susi Kriemler

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EFFECT OF A GENERAL SCHOOL-BASED PHYSICAL ACTIVITY INTERVENTION ON BONE MINERAL CONTENT AND DENSITY: A CLUSTER-RANDOMIZED CONTROLLED TRIAL

ABSTRACT

Specific physical loading leads to enhanced bone development during childhood. A general physical activity program mimicking a real-life situation was successful at increasing general physical health in children. Yet, it is not clear whether it can equally increase bone mineral mass. We performed a cluster-randomized controlled trial in children of both gender and different pubertal stages to determine whether a school-based physical activity program during one school-year influences bone mineral content (BMC) and density (BMD), irrespective of gender. Twenty-eight first and fifth grade (6–7 and 11–12 year-old) classes were cluster randomized to an intervention (INT, 16 classes, n=297) and control (CON; 12 classes, n=205) group. The intervention consisted of a multi-component physical activity intervention including daily physical education with at least 10 min of jumping or strength training exercises of various intensities. Measurements included anthropometry, and BMC and BMD of total body, femoral neck, total hip and lumbar spine using dual-energy X-ray absorptiometry (DXA). Physical activity was assessed by accelerometers and Tanner stages by questionnaires. Analyses were performed by a regression model adjusted for gender, baseline height and weight, baseline physical activity, post-intervention pubertal stage, baseline BMC, and cluster. 275 (72%) of 380 children who initially agreed to have DXA measurements had also post-intervention DXA and physical activity data. Mean age of prepubertal and pubertal children at baseline was 8.7±2.1 and 11.1± 0.6 years, respectively. Compared to CON, children in INT showed statistically significant increases in BMC of total body, femoral neck, and lumbar spine by 5.5%, 5.4% and 4.7% (all p<0.05), respectively, and BMD of total body and lumbar spine by 8.4% and 7.3% (both p<0.01), respectively. There was no gender*group, but a pubertal stage*group interaction consistently favoring prepubertal children. A general school-based physical activity intervention can increase bone health in elementary school children of both genders, particularly before puberty.

INTRODUCTION

A major contributing factor to osteoporosis in advancing age is a low peak bone mass after the growing years[(1)]. Bone mass can be increased before the end of growth by specific physical exercise, a finding that has been widely proven in animals and humans, comprising children of both genders and in different stages of puberty[(1-3)]. However, general physical activity based public health interventions in community real life situations that focus not only on bone but also on other positive health aspects like aerobic fitness or cardiovascular risk factors in a large representative child population are sparse[(4-6)]. We conducted a trial which was successful at inducing multiple beneficial health effects with increased physical activity, aerobic fitness, decreased body fat and cardiovascular risk factors in a randomly selected cohort of elementary school children[7].

We have previously shown in a cross-sectional study[8] that for the same degree of physical exercise, girls' bones appeared to have less bone mineral compared with boys'. There is still not enough evidence in the literature to accept or reject our hypothesis, since no single randomized controlled trial was run to specifically address this difference, reducing our knowledge to programs that were performed in prepubertal boys and girls[9, 10]. If our hypothesis of different sensitivity to loading was true, it could have important implications in terms of timing, intensity, and duration of physical exercise to improve bone gain in both genders, from the perspective of an early primary prevention of osteoporosis.

To address these questions more precisely, we conducted a cluster-randomized controlled trial to determine whether a general school-based physical intervention program during one school-year increases bone mineral content (BMC) and bone mineral density (BMD) in favor of the intervention group compared with controls. Since the program was administered to a general population of elementary school children, we also assessed the sex and maturity specific bone response to the intervention.

MATERIALS AND METHODS

Study design and study population

The design of the study has been previously described in detail[11]. Classes were randomly selected from 919 schools in two (Aargau, Baselland) of the 26 provinces of Switzerland compromising about 10% of the Swiss population. In order to be representative of Switzerland, classes were additionally stratified for living area (rural vs urban) and ethnicity (at least 10-30% migrants). Of all classes that fulfilled the stratification criteria, 28 first (6-7 years) and fifth (11-12 years) grade classes were randomized to the intervention (16 classes from 9 schools) or the control group (12 classes from 6 schools). For the intervention arm, a higher number of classes (i.e., 16 of a total of 28) was chosen in view of specific analyses to be conducted only in this arm. Classes from the intervention and control group were located in different villages or towns. Informed consent was given by all participating children and their parents. Baseline (August 2005) and post-intervention (June 2006) measurements were done at school within the same three week period for all children, with the intervention period lasting nine months in between. The study was approved by all local ethics committees. Written informed consent was provided by the children and at least one of their parents.

Intervention

As described in detail previously[7, 11] children in both groups had three physical education lessons per week, which are compulsory. The intervention took place on the level of the class. Classes in the intervention group received two additional physical education lessons which resulted in one physical education lessons on each school day. While the three regular weekly physical education lessons (45 minutes each) were given by the usual classroom teachers according to the specified study curriculum, the two additional weekly lessons (45 minutes each) were taught mostly outdoors by physical education teachers. All five physical education lessons for the children in the intervention group were prepared by a team of expert physical education teachers and each included at least ten minutes of jumping activities like as hopping, jumping up and down stairs, rope skipping etc. Ground reaction forces were not measured. The same curriculum was provided to all intervention classes. In addition, three to five short activity breaks (2 to 5 minutes each) during academic lessons, comprising motor skill tasks such as jumping around on one leg, balancing on one leg, power games or coordinative tasks were introduced every day. Most of these tasks were skill oriented, while about every sixth task focusing on bone loading. The children received daily physical activity homework of about 10 minutes duration prepared by the physical education teachers that included aerobic, strength or motor skill tasks like tooth brushing while standing on one leg, jumping up and down the stairs, rope jumping. This program has been shown to positively influence the cardiovascular system[7]. Bone loading and muscle building activities were included in about 40% of all exercises. Children and parents of the control group were not informed of the existence of the intervention program in other schools. The teachers in the control group knew about the intervention arm, but were not informed about its content.

Anthropometry and physical activity

Children's height and mass were measured in T-Shirt, shorts and barefoot using a Harpenden stadiometer (Holtain) with an accuracy of 0.1 cm and an electronic scale (Seca) with an accuracy of 0.1 kg. Parents and children were asked to rate children's pubertal stage by a questionnaire with a simple explanation and line drawings of the Tanner stages which has been validated and described as reasonably accurate[12]. Pubertal stage was defined as prepubertal (Tanner stage 1) and early pubertal (Tanner stage 2 and 3) based on breast development for girls and pubic hair for boys. Children with pubertal stages >3 were not included in the analysis (n=11). Calcium intake was assessed by a validated questionnaire[13], adapted to the Swiss nutrition where daily calcium intake was calculated in milligrams per day.

Physical activity was monitored by an accelerometer (MTI/CSA 7164, Actigraph, Shalimar, FL, USA) which was worn continuously around the hip for 7 days. The sampling time was set to 1 minute. Based on our pilot work and other reports[14] time periods with over 15 minutes of continuous zero values were considered to represent periods when the monitors were not worn and were omitted before analyses. An individual child's physical activity data were included if at least three week days and one weekend day of measurements with a minimum of 12 hours for week days and 10 hours for weekend days were recorded. If not the whole week was measured, data from monitored days were extrapolated to the remaining week by distinguishing week days and weekend days. Physical activity was expressed as average counts min^{-1} (CPM) and vigorous physical activity (VPA) as minutes above 3000 counts min^{-1} [(15)].

Bone and body composition

Body composition and bone were measured using dual-energy x-ray absorptiometry (DXA; Hologic QDR-4500) located in a truck travelling to each school. Body composition was assessed by the three-compartment model, including fat mass, bone mineral content, and bone mineral free lean tissue. Bone mineral content (BMC, g) and areal bone mineral density (BMD, g/cm^2) were determined for total body, femoral neck, and L1-L4 vertebrae in antero-posterior view. BMC and BMD values were z-transformed using grade- and gender-specific means and standard deviations derived from the whole sample at baseline and at the post-intervention measurements. The coefficient of variation of repeated measurements for femur, lumbar spine and total body determined in young healthy adults varies between 1-1.6% for BMD, and 0.3-3% for BMC[(16)].

Statistical analysis

Statistical analyses were based on the intention-to-treat principle and results are reported at the level of individuals. Baseline measurements of the two groups were compared using a regression model with adjustment for cluster. Since the study population consisted of two distinct age groups, all analyses estimating intervention effects on outcomes were done using internal z-scores based on pubertal stage (prepubertal (Tanner stage 1) and early pubertal (Tanner stage 2 and 3)) and gender. We used mixed linear models with z-scores at follow-up as dependent variables, group, gender and post-intervention pubertal stage, baseline height and weight as fixed factors, school class as random effect, and the respective baseline z-score as covariate. School class was the smallest cluster in the sampling design and was therefore introduced as a random effect. For each outcome measure, the size of the intervention effect is reported as difference in its average internal z-scores at follow-up between the intervention and control group after adjustment. Secondary analyses were performed by testing whether baseline physical activity or calcium intake had an effect on the intervention results, and interactions of the intervention with gender and pubertal stage. Due to a technical defect of the DXA unit, we lost 36 children of the control group at baseline. The initial power calculation was performed for the primary outcomes (i.e. physical activity, aerobic fitness, sum of four skin folds and quality of life) of the study[(7)]. Due to the radiation exposure, parents and children had to give a special consent for participation in the DXA measurements. Analyses were performed using Stata version 11.0.

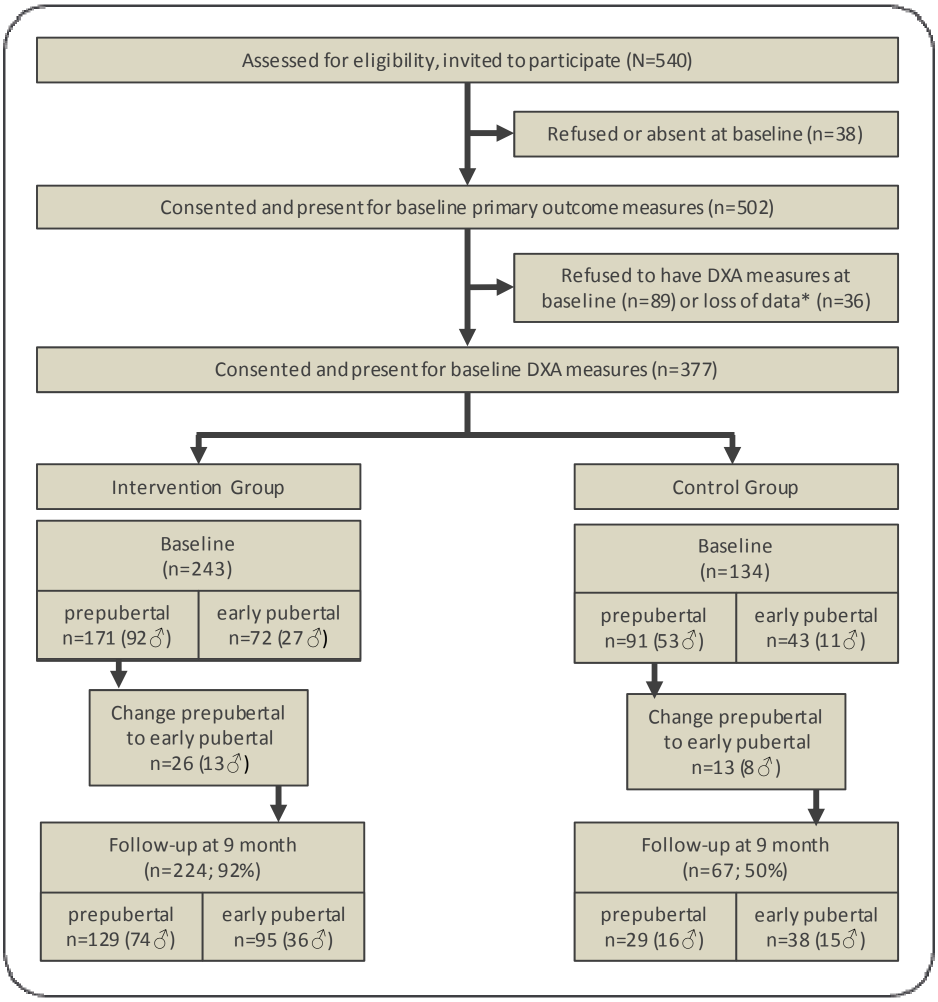

Figure 8.1 Flow sheet of participants through the study. *Loss due to a technical defect of the DXA unit.

RESULTS

Participant characteristics

A participants flow is given in Figure 8.1. A total of 502 children entered in the study. Of those, 377 (75 %) children agreed to take part in baseline DXA measurements, of those 291 (58 %) had also post-intervention DXA measurements. Children with baseline and post-intervention DXA measurements did not differ from the remaining children in gender, age, height, mass, pubertal stage and body mass index at baseline. Also, the characteristics of the 36 lost children of the control group did not differ from those of the included children, irrespective of group assignment.

Participant characteristics are given in Table 8.1. There were no significant differences at baseline between the two groups, except higher BMC values in pubertal controls for whole body and lumbar spine (*p*=0.037 and *p*=0.007, respectively) compared to pubertal intervention group. 217 of the 291 children had physical activity measurements and 278 of 291 children reported calcium intake. Children with physical activity or calcium data did not differ from the remaining children in terms of anthropometric and bone parameters.

Table 8.1 Baseline characteristics of the participating children, according to pubertal stage at follow-up.

	Intervention group		Control group	
	Prepubertal	Early pubertal	Prepubertal	Early pubertal
n	129	95	29	38
Age (years)	8.3 ± 2.0	10.9 ± 1.0	7.8 ± 1.8	11.2 ± 0.9
Weight (kg)	27.8 ± 7.0	38.7 ± 8.0	27.2 ± 9.0	41.2 ± 8.5
Height (cm)	129 ± 12	146 ± 7	128 ± 12	149 ± 7
Body-mass index (kg/m^2)	16.4 ± 1.8	18.2 ± 2.9	16.2 ± 2.5	18.5 ± 3.1
Fat mass (%)	19.8 ± 5.6	23.3 ± 6.8	19.3 ± 5.2	22.7 ± 6.5
Fat free mass (kg)	18.2 ± 4.9	25.0 ± 4.4	17.7 ± 5.5	27.0 ± 5.3
Calcium intake (mg/d)	950 ± 353	1066 ± 374	891 ± 216	990 ± 565
Physical activity (cpm/d)	779 ± 175	652 ± 192	876 ± 212	708 ± 279
Vigorous physical activity (min/d)[a]	45 ± 22	41 ± 23	57 ± 24	50 ± 30
BMC Whole body (g)	659 ± 179	915 ± 154	651 ± 211	1002 ± 221[b]
BMC Femoral neck (g)	2.15 ± 0.69	2.92 ± 0.55	2.13 ± 0.71	3.12 ± 0.61
BMC Lumbar spine (g)	20.39 ± 5.13	26.99 ± 4.75	20.4 ± 5.57	29.91 ± 7.43[b]
BMD Whole body (g/cm^2)	0.62 ± 0.08	0.73 ± 0.06	0.62 ± 0.10	0.76 ± 0.08
BMD Femoral neck (g/cm^2)	0.64 ± 0.08	0.69 ± 0.07	0.65 ± 0.11	0.72 ± 0.10
BMD Lumbar spine (g/cm^2)	0.56 ± 0.08	0.65 ± 0.08	0.57 ± 0.09	0.68 ± 0.12

Values are means ± standard deviations; cpm, counts per minute; BMC, bone mineral content; BMD, bone mineral density.
[a]>3000 counts per minutes (Ekelund, 2004).
[b] different from pubertal intervention group (p≤0.05). Pubertal stages are prepubertal (tanner stage=1) and early pubertal (tanner stage 2-3).

Intervention effects

Table 8.2 shows the main results including the baseline data and the adjusted differences at post-intervention in BMC in both groups. After adjustment for baseline height, baseline weight, baseline BMC, sex, post-intervention pubertal stage and cluster, significant group effects could be observed for whole body, femoral neck and lumbar spine BMC. Compared to controls, the intervention group showed larger increases in whole body BMC by 0.138 (0.060 to 0.216, p=0.001) z-score units, which corresponds to an increase of 43.3 mg or 5.5% of the mean baseline value. The relative increases of the intervention versus control group of femoral neck and lumbar spine BMC were 5.4% (p=0.037) and 4.7% (p=0.01), respectively. Compared to controls, children of the intervention group increased whole body BMD by 0.212 (0.088 to 0.337; p=0.001) z-score units, corresponding to 8.4% of mean baseline values, and lumbar spine BMD by 0.184 (0.083 to 0.285; p≤0.001) z-score units equivalent to 7.3% of mean baseline values, respectively. No significant intervention effect could be found for femoral neck BMD (0.045 (-0.091 to 0.181); p=0.513).

Secondary analyses were performed with inclusion of baseline physical activity. These analyses could not be performed for all children, since only a subsample of children was willing to wear an accelerometer. Children with and without accelerometer data did not differ in anthropometric and bone measurements. Additional adjusting of our model for baseline physical activity, (i. e. average physical activity or vigorous physical activity) and calcium intake did not change the results.

Influence of pubertal stage and gender

The interaction term gender*group did not have a significant effect on the model for any BMC and BMD parameters, indicating that there were no differences in response to the intervention program between boys and girls.

However, the interaction term pubertal stage*group showed a significant effect on whole body BMC (β-coefficient of interaction: -0.112 (95%-confidence interval: -0.206 to -0.018); p=0.020), femoral neck BMC (-0.235 (-0.373 to -0.098); p=0.001) and lumbar spine BMD (-0.182 (-0.289 to -0.075); p=0.001) indicating a larger intervention effect in prepubertal than pubertal children.

Table 8.2 Effects of the intervention on bone mineral content and density.

	Baseline bone mineral content/density		Adjusted difference at follow-up	
	Intervention group	Control group	Coefficient (95% CI)	*p* value
Bone mineral content				
Whole body (g)	768 ± 211	850 ± 277	0.138 (0.06 to 0.216)	0.001
Femoral neck (g)	2.48 ± 0.74	2.69 ± 0.82	0.136 (0.008 to 0.264)	0.037
Lumbar spine (g)	23.18 ± 5.94	25.79 ± 8.16	0.118 (0.028 to 0.207)	0.010
Bone mineral density				
Whole body (g/cm^2)	0.67 ± 0.09	0.70 ± 0.12	0.212 (0.088 to 0.337)	0.001
Femoral neck (g/cm^2)	0.66 ± 0.08	0.69 ± 0.11	0.045 (-0.091 to 0.181)	0.513
Lumbar spine (g/cm^2)	0.60 ± 0.09	0.63 ± 0.12	0.184 (0.083 to 0.285)	≤0.001

Adjusted difference in average *z-score* of respective outcome at follow-up between intervention and control group with 95% confidence interval and *p* value, adjusted for sex, pubertal stage, baseline height, baseline weight, interaction pubertal stage*group and *z-score* of baseline bone mineral content/density.

DISCUSSION

This randomized controlled trial showed that a general school-based physical activity intervention over nine months aiming to improve general physical and cardiovascular health also improved bone health in pre- and early pubertal children. Our program resulted in BMC and BMD changes of total body, lumbar spine and femoral neck in the range of 5-8% in favor of the intervention compared to the control group which is highly relevant. Overall, prepubertal children benefitted more from the program than early pubertal children, while there was no difference for genders. Of note, this multi-component physical activity intervention not only improved bone health, but was also effective at improving physical activity, aerobic fitness, body fat and cardiovascular risk factors in children of the intervention compared to the control group. This is from a public health perspective unique and novel. Our program led to multiple, important positive health effects in a setting that was community based, well representative including children of both genders and different pubertal stages, and mimicked a real-life situation that may be applicable to any child of this age. Our sampling included rural and urban areas with a migrant population of 10-30%, comparable to many Western countries.

Several intervention studies demonstrated that physical loading improved bone mineral content and/or density of various sites in children of different ages and pubertal stages(1, 3). The reported changes in BMC ranged from 0.9 to 3.9% for studies in prepubertal children and from 0.9 to 6.2% in early pubertal children for an extrapolated time of 6 months. Adjusted for the same duration, our effects ranged from 3.1 to 3.5% for BMC and from 4.8 to 5.6% for BMD values, which is comparable. Existing intervention trials including ours used different jumping activities in regular physical education lessons(9, 17, 18) or simple jumping programs during physical education lessons or in classrooms(5, 10) usually 3 times/week for 10 to 30 minutes which is thought to be sufficient for an osteogenic effect(19). The jumping activities in this study could easily be introduced in the physical education lessons and/or added as short bouts over the schoolday, and thereby not only improving bone mass, but also cardiovascular health.

There is some evidence, that pre and early puberty represents an ideal "window of opportunity" to intervene with an exercise program(19-21). However, it remains unclear whether puberty *per se* increases sensitivity of bone to physical loading which is very well plausible considering the bone-stimulating increases in hormones that occur with entrance into puberty(22). While our data support findings of previous studies(21, 23), that documented the benefit of exercise occurring particularly before puberty, others found that loading during puberty was related to increased bone mass (24, 25). Controversy is even further enhanced by the elegant racket sport studies which have the potential to control for genetics, nutrition, stage of puberty and the hormonal and metabolic milieu. In girls, bone mass differences in favor of the playing arm occurred during the prepubertal years and did not increase until the end of menarche(21), while in boys bone accrual in favor of the playing arm persistently increased from prepuberty to the peripubertal years(24). There is, however, general agreement that exercise related osteogenic effects seem to be lower, once the final stage of maturation is reached(21, 24, 26). Future studies might be able to better address and tease out important confounding factors, such as precise measurement of puberty onset and course, body shape adjusted ground reaction forces, quantitative and qualitative aspects of lean body mass, and background loading of bone outside the intervention.

Animal studies(27), our cross-sectional data(8) and an elegant school-based intervention study(28) applying the recognized optimal regimen of exercise in form of short, intense loading interspersed with recovery periods(29) showed that there may be a sex-specific difference in response to physical activity, suggesting that especially before puberty, boys' bones were more sensitive to physical activity than girls' bones. However, the current analyses obtained in our randomized controlled trial showed in concert with others[9, 30] that both sexes benefitted to the same extent to the same physical activity program. Reasons for the discrepant finding among the studies may be related to motivational differences, different timing of the pubertal development or the different background physical activity, for which there was often no control[28].

This physical activity program was implemented into the normal school curriculum and was therefore mandatory which guaranteed compliance of all children and avoided a potential stigmatization of overweight or inactive children. It also included those who might have dropped out if given a free choice, and gave all children an equal chance to benefit from this type of intervention. Compliance of the teachers was not measured directly, but was optimized as much as possible by providing them with a content plan for all physical education lessons and through weekly visits by the physical education specialists who performed the extra lessons. From a maintenance perspective, unsolicited approaches might be more appropriate and lead to higher long-term approval rates due to voluntariness and self-determination[31]. However, the feedback from teachers and children showed that both parties enjoyed the program. 90% of children and 70% of teachers wanted the program to continue[7], which is an important and promising condition for the sustainability of such a program.

Strengths of the study were its nature of being a randomized controlled trial in a representative population of elementary school children comprising children of different pubertal stage and both genders, its high adherence rate, the sufficient duration of one academic year that leads to multiple beneficial health effects including improved bone health. From a public health perspective this overall effect is unique and very promising[7]. Moreover, in contrast to many bone intervention studies[5, 10, 23, 26], we controlled our results for the randomization unit. This procedure controls for the fact, that the interventions take place on the level of the class and effects might be influenced by the teacher[32]. This is very important, since exceptionally good effects in one class could result in an overall significant intervention effect by compensating negative effects in (most) other classes. A further strength of the study was the inclusion of an objective measure of physical activity by accelerometers. Such public health interventions are usually short (i.e. usually some minutes up to an hour three to five times a week) and leave plenty of time for physical activity during the remaining of the day. This unobserved time might introduce a major bias by significantly influencing the bone results, potentially even more than the intervention per se. Our results, contrary to many other intervention studies[10, 17, 18], were adjusted for the “background” physical activity of the children (i.e. baseline physical activity) which reduced the chance that the intervention effect was caused by extra-curricular physical. In addition, those who did control for physical activity[5, 22, 25, 30, 33], mainly used questionnaires with inherent low reliability and validity especially in children[34].

One limitation of the current study is the loss of data in the control group due to a technical defect of the DXA computer that stored the data. This reduced the sample size of our prepubertal control group considerably and questions the representability of the group. Another limitation is the sample size reduction by non willingness to participate in the DXA measurements. This is a problem of research that exposes children to some sort of radiation, even though the dose of a DXA scan used in this study was very low and comparable to the natural radiation by a walk in the mountains or a transatlantic flight(35). The fact that children who participated versus those not participating in the DXA measurements were not different in respect to anthropometric measurements and physical activity, does exclude a major selection bias. It is also reassuring that age- and gender related z-scores in our baseline sample were in general (with a few exceptions) not significantly different from published norm values(36, 37) although this comparison among children of different socio-cultural background may be questionable.

A 10% increase in peak bone mass would delay the onset of osteoporosis by 13 years(38) and reduce the osteoporotic fracture risk by up to 50% in women after menopause(39). With our intervention program, we reached an increased bone development in intervention children by up to 8.4% within only one academic year. Moreover, this intervention did not only lead to an improved bone health but also affected physical activity, fitness and cardiovascular risk factors positively, which is most important from a public health aspect. Future research should include intervention programs over several years and long term follow-up to determine whether these effects persist as suggested(40), but also critically questioned(41).

CONCLUSION

A school-based, multi-component physical activity intervention of one academic year improved bone health of elementary school children simultaneously. BMC and BMD were positively affected in pre- and early pubertal boys and girls with higher effects during prepuberty. Implementation of such a program may help to improve bone and overall health of children.

REFERENCES

(1) Rizzoli R, Bianchi ML, Garabedian M, McKay HA, Moreno LA. Maximizing Bone Mineral Mass Gain During Growth for the Prevention of Fractures in the Adolescents and the Elderly. Bone. 2010; 46(2): 294.

(2) Forwood MR. Physical Activity and Bone Development During Childhood: Insights from Animal Models. J Appl Physiol. 2008; 105(1): 334.

(3) Hind K, Burrows M. Weight-Bearing Exercise and Bone Mineral Accrual in Children and Adolescents: A Review of Controlled Trials. Bone. 2007; 40(1): 14.

(4) Macdonald HM, Kontulainen SA, Khan KM, McKay HA. Is a School-Based Physical Activity Intervention Effective for Increasing Tibial Bone Strength in Boys and Girls? J Bone Miner Res. 2007; 22(3): 434.

(5) McKay HA, MacLean L, Petit M, MacKelvie-O'Brien K, Janssen P, Beck T, et al. "Bounce at the Bell": A Novel Program of Short Bouts of Exercise Improves Proximal Femur Bone Mass in Early Pubertal Children. Br J Sports Med. 2005; 39(8): 521.

(6) McKay H, Smith E. Winning the Battle against Childhood Physical Inactivity: The Key to Bone Strength? J Bone Miner Res. 2008; 23(7): 980.

(7) Kriemler S, Zahner L, Schindler C, Meyer U, Hartmann T, Hebestreit H, et al. Effect of School Based Physical Activity Programme (Kiss) on Fitness and Adiposity in Primary Schoolchildren: Cluster Randomised Controlled Trial. Br Med J. 2010; 340(feb23 1): c785.

(8) Kriemler S, Zahner L, Puder JJ, Braun-Fahrlander C, Schindler C, Farpour-Lambert NJ, et al. Weight-Bearing Bones Are More Sensitive to Physical Exercise in Boys Than in Girls During Pre- and Early Puberty: A Cross-Sectional Study. Osteoporos Int. 2008; 19(12): 1749.

(9) MacKelvie KJ, Petit MA, Khan KM, Beck TJ, McKay HA. Bone Mass and Structure Are Enhanced Following a 2-Year Randomized Controlled Trial of Exercise in Prepubertal Boys. Bone. 2004; 34(4): 755.

(10) Fuchs RK, Bauer JJ, Snow CM. Jumping Improves Hip and Lumbar Spine Bone Mass in Prepubescent Children: A Randomized Controlled Trial. J Bone Miner Res. 2001; 16(1): 148.

(11) Zahner L, Puder JJ, Roth R, Schmid M, Guldimann R, Puhse U, et al. A School-Based Physical Activity Program to Improve Health and Fitness in Children Aged 6-13 Years ("Kinder-Sportstudie Kiss"): Study Design of a Randomized Controlled Trial [Isrctn15360785]. BMC Public Health. 2006; 6: 147.

(12) Duke PM, Litt IF, Gross RT. Adolescents' Self-Assessment of Sexual Maturation. Pediatrics. 1980; 66(6): 918.

(13) Molgaard C, Sandstrom B, Michaelsen KF. Evaluation of a Food Frequency Questionnaire for Assessing of Calcium, Protein and Phosphorus Intakes in Children and Adolescents. Scand J Nutr. 1998; 42(1): 2.

(14) Andersen LB, Harro M, Sardinha LB, Froberg K, Ekelund U, Brage S, et al. Physical Activity and Clustered Cardiovascular Risk in Children: A Cross-Sectional Study (the European Youth Heart Study). Lancet. 2006; 368(9532): 299.

(15) Ekelund U, Sardinha LB, Anderssen SA, Harro M, Franks PW, Brage S, et al. Associations between Objectively Assessed Physical Activity and Indicators of Body Fatness in 9- to 10-Y-Old European Children: A Population-Based Study from 4 Distinct Regions in Europe (the European Youth Heart Study). Am J Clin Nutr. 2004; 80(3): 584.

(16) Bonjour JP, Chevalley T, Ammann P, Slosman D, Rizzoli R. Gain in Bone Mineral Mass in Prepubertal Girls 3.5 Years after Discontinuation of Calcium Supplementation: A Follow-up Study. Lancet. 2001; 358(9289): 1208.

(17) Valdimarsson O, Linden C, Johnell O, Gardsell P, Karlsson MK. Daily Physical Education in the School Curriculum in Prepubertal Girls During 1 Year Is Followed by an Increase in Bone Mineral Accrual and Bone Width--Data from the Prospective Controlled Malmo Pediatric Osteoporosis Prevention Study. Calcif Tissue Int. 2006; 78(2): 65.

(18) Hasselstrom HA, Karlsson MK, Hansen SE, Gronfeldt V, Froberg K, Andersen LB. A 3-Year Physical Activity Intervention Program Increases the Gain in Bone Mineral and Bone Width in Prepubertal Girls but Not Boys: The Prospective Copenhagen School Child Interventions Study (Coscis). Calcif Tissue Int. 2008; 83(4): 243.

(19) Hughes JM, Novotny SA, Wetzsteon RJ, Petit MA. Lessons Learned from School-Based Skeletal Loading Intervention Trials: Putting Research into Practice. Med Sport Sci. 2007; 51: 137.

(20) MacKelvie KJ, Khan KM, McKay HA. Is There a Critical Period for Bone Response to Weight-Bearing Exercise in Children and Adolescents? A Systematic Review. 2002; 36(4): 250.

(21) Bass SL, Saxon L, Daly RM, Turner CH, Robling AG, Seeman E, et al. The Effect of Mechanical Loading on the Size and Shape of Bone in Pre-, Peri-, and Postpubertal Girls: A Study in Tennis Players. J Bone Miner Res. 2002; 17(12): 2274.

(22) MacKelvie KJ, McKay HA, Petit MA, Moran O, Khan KM. Bone Mineral Response to a 7-Month Randomized Controlled, School-Based Jumping Intervention in 121 Prepubertal Boys: Associations with Ethnicity and Body Mass Index. J Bone Miner Res. 2002; 17(5): 834.

(23) MacKelvie KJ, McKay HA, Khan KM, Crocker PR. A School-Based Exercise Intervention Augments Bone Mineral Accrual in Early Pubertal Girls. J Pediatr. 2001; 139(4): 501.

(24) Ducher G, Daly RM, Bass SL. Effects of Repetitive Loading on Bone Mass and Geometry in Young

Male Tennis Players: A Quantitative Study Using Mri. J Bone Miner Res. 2009; 24(10): 1686.
(25) Gunter K, Baxter-Jones ADG, Mirwald RL, Almstedt H, Fuchs RK, Durski S, et al. Impact Exercise Increases Bmc During Growth: An 8-Year Longitudinal Study. J Bone Miner Res. 2008; 23(7): 986.
(26) Heinonen A, Sievanen H, Kannus P, Oja P, Pasanen M, Vuori I. High-Impact Exercise and Bones of Growing Girls: A 9-Month Controlled Trial. Osteoporos Int. 2000; 11(12): 1010.
(27) Wallace JM, Rajachar RM, Allen MR, Bloomfield SA, Robey PG, Young MF, et al. Exercise-Induced Changes in the Cortical Bone of Growing Mice Are Bone- and Gender-Specific. Bone. 2007; 40(4): 1120.
(28) Macdonald H, Kontulainen S, Petit M, Janssen P, McKay H. Bone Strength and Its Determinants in Pre- and Early Pubertal Boys and Girls. Bone. 2006; 39(3): 598.
(29) Robling AG, Hinant FM, Burr DB, Turner CH. Shorter, More Frequent Mechanical Loading Sessions Enhance Bone Mass. Med Sci Sports Exerc. 2002; 34(2): 196.
(30) MacKelvie KJ, Khan KM, Petit MA, Janssen PA, McKay HA. A School-Based Exercise Intervention Elicits Substantial Bone Health Benefits: A 2-Year Randomized Controlled Trial in Girls. Pediatrics. 2003; 112(6 Pt 1): e447.
(31) Deci EL, Ryan RM. Intrinsic Motivation and Self-Determination in Human Behavior. Perspectives in Social Psychology. New York, N.Y.: Plenum Press; 1985.
(32) Campbell MK, Elbourne DR, Altman DG. Consort Statement: Extension to Cluster Randomised Trials. Br Med J. 2004; 328(7441): 702.
(33) Petit MA, McKay HA, MacKelvie KJ, Heinonen A, Khan KM, Beck TJ. A Randomized School-Based Jumping Intervention Confers Site and Maturity-Specific Benefits on Bone Structural Properties in Girls: A Hip Structural Analysis Study. J Bone Miner Res. 2002; 17(3): 363.
(34) Sallis JF. Self-Report Measures of Children's Physical Activity. J Sch Health. 1991; 61: 215.
(35) Njeh CF, Fuerst T, Hans D, Blake GM, Genant HK. Radiation Exposure in Bone Mineral Density Assessment. Appl Radiat Isot. 1999; 50(1): 215.
(36) Kalkwarf HJ, Zemel BS, Gilsanz V, Lappe JM, Horlick M, Oberfield S, et al. The Bone Mineral Density in Childhood Study: Bone Mineral Content and Density According to Age, Sex, and Race. J Clin Endocrinol Metab. 2007; 92(6): 2087.
(37) van der Sluis IM, de Ridder MA, Boot AM, Krenning EP, de Muinck Keizer-Schrama SM. Reference Data for Bone Density and Body Composition Measured with Dual Energy X Ray Absorptiometry in White Children and Young Adults. Arch Dis Child. 2002; 87(4): 341.
(38) World Health Organization. Assessment of Fracture Risk and Its Application to Screening for Postmenopausal Osteoporosis. Report of a Who Study Group. World Health Organ Tech Rep Ser. 1994; 843: 1.
(39) Marshall D, Johnell O, Wedel H. Meta-Analysis of How Well Measures of Bone Mineral Density Predict Occurrence of Osteoporotic Fractures. Br Med J. 1996; 312(7041): 1254.
(40) Kontulainen S, Kannus P, Haapasalo H, Sievanen H, Pasanen M, Heinonen A, et al. Good Maintenance of Exercise-Induced Bone Gain with Decreased Training of Female Tennis and Squash Players: A Prospective 5-Year Follow-up Study of Young and Old Starters and Controls. J Bone Miner Res. 2001; 16(2): 195.
(41) Seeman E. An Exercise in Geometry. J Bone Miner Res. 2002; 17(3): 373.

CHAPTER 9

3-year follow-up results of a school-based physical activity intervention on bone mineral content and density: a randomized controlled trial

Ursina Meyer
Dominique Ernst
Lukas Zahner
Christian Schindler
Jardena J. Puder
Marius Kränzlin
René Rizzoli
Susi Kriemler

in submission

3-YEAR FOLLOW-UP RESULTS OF A SCHOOL-BASED PHYSICAL ACTIVITY INTERVENTION ON BONE MINERAL CONTENT AND DENSITY: A RANDOMIZED CONTROLLED TRIAL

ABSTRACT

Background: There is growing evidence that osteoporosis has its origins in childhood. Physical activity has been shown to positively influence bone mass accrual during growing years. We have previously shown that a general school based physical activity intervention over nine months improved bone mineral content (BMC) and density (BMD) in primary school children. However, from a public health perspective, the major key is whether these effects persist into adolescence. We therefore performed a 3-year follow-up measurement to investigate whether the beneficial intervention effects of a general school based physical activity intervention program on BMC and BMD are maintained three years after the program has ceased. **Methods:** All children from the 28 randomly selected first and fifth grade classes (Intervention group: 16 classes, n=297; control group: 12 classes, n=205) that had participated in KISS (Kinder- und Jugendsportstudie) were contacted three years after cessation of the intervention program. The intervention included daily physical education including daily impact loading activities (i.e. two additional lessons per week, on top of three regular lessons), short physical activity breaks during academic lessons, and daily physical activity homework. Measurements included anthropometry, pubertal stages, and BMC/BMD for total body, femoral neck, total hip and lumbar spine using dual-energy X-ray absorptiometry (DXA). Analyses were performed by a regression model with sex- and pubertal stage adjusted z-score of BMC or BMD as outcome, adjusted for gender, baseline height, baseline weight, pubertal stage at follow-up, baseline BMC or BMD, and cluster. **Results:** Of the 377 (75%) children participating in baseline DXA measurements, 214 (57%) participated at follow-up DXA measurements. At follow-up, INT showed significantly higher BMC at femoral neck (adjusted difference: 0.180 (95% confidence interval: 0.007 – 0.354); p=0.042) and total hip (0.167 (0.014 – 0.320); p=0.032) compared to CON, and a tendency towards higher total body BMC (0.137 (-0.004 – 0.278); p=0.056). Compared to CON, INT showed higher BMD only for total body (0.145 (0.015 – 0.276); p=0.028). No differences could be found at lumbar spine BMC and BMD, and femoral neck and total hip BMD. **Conclusion:** Beneficial effects of a nine month intervention persisted over three years at weight-bearing sites where physical activity acts most. From a public health perspective, these effects are promising but longer follow-up periods are needed to document whether these effects persist into adulthood.

INTRODUCTION

There is growing evidence that osteoporosis has its origins in childhood. A key determinant of fracture risk later in life is the relationship between bone mineral mass and bone structure. Given that 60% of the risk of osteoporosis can be explained by the amount of bone mass accrued by early adulthood[1], maximizing peak bone mass may be an important factor for the prevention of osteoporosis[2]. While 60 to 80% of peak bone mass variance is explained by genetic factors[3-5], physical exercise before the end of growth has been shown to be an important behavioral and modifiable determinant of bone mass in animals and humans, comprising children of both genders and of different stages of puberty[2, 6-8].

Results from physical activity interventions in children aiming at increasing bone mass were effective with reported changes in BMC and bone strength ranging from 1 to 8%[7, 9]. While most of the existing intervention studies used a targeted design including defined jump activities[10, 11], we applied a general school based physical activity intervention over nine months with one aim to improving bone mass[12], but in addition also physical activity, aerobic fitness, body fat and cardiovascular risk in children[13]. Even if results were promising showing beneficial effects on physical activity, aerobic fitness, body fat, a cardiovascular risk score and bone mineral, the major key from a public health perspective is whether these effects persist into adulthood.

Existing longitudinal data showed that physically active children maintained their higher bone mass compared to less active peers into early adulthood, even independently of their actual physical activity level[14]. Existing follow-up results from bone tailored jumping intervention studies support this finding[15, 16]. Even though decreasing, the intervention effect on bone mass was reported to be sustained over four and eight years of follow-up[15, 16]. However, it remains unclear, whether the effects of a more general physical activity intervention not only targeting bone health could also be maintained over a period of three years.

We therefore performed a follow-up measurement to investigate whether the beneficial intervention effects on BMC and BMD of a general school based physical activity intervention program over nine months are maintained three years after the program has ceased.

METHODS

Study design and study population

The design of the study has been previously described in detail[13, 17]. Originally, classes were randomly selected from 919 schools in two (Aargau, Baselland) of the 26 provinces of Switzerland compromising about 10% of the Swiss population. In order to be representative of Switzerland, classes were stratified for living area (rural vs. urban) and ethnicity (at least 10–30% migrants). Of all classes that fulfilled the stratification criteria, 28 first (6–7 years) and fifth (11–12 years) grade classes were randomized to the intervention (16 classes from 9 schools) or the control group (12 classes from 6 schools). Classes from the intervention and control group were located in different villages or towns and did not know from each other. Informed consent was given by all participating children and their parents. Baseline (August 2005) and post-intervention (June 2006) measurements were done at school within the same three week period for all children, with the intervention period lasting nine months in between. For the follow-up measurements, all children were contacted in written form trough their actual schools and if necessary, individually by phone call. The former first grade children were tested in their actual schools in June 2009. The measurements of the former fifth grade children were planned at two weekend days, because the former fifth grade children were dispersed in different schools as they had changed to secondary school. However, since the response rate was very low (21% of all potential fifth grade children), we decided to organize the measurements during school-time in a centrally located new school that was easily reachable for all. These measurements took place from August and November 2009. The study was approved by all local ethics committees. Written informed consent was provided by the children and at least one of their parents.

Intervention

The intervention has been described in detail previously(13, 17). During the intervention time of nine months, children in both groups had three physical education lessons (45 min each) per week given by the classroom teachers, which are compulsory by the Swiss law. Classes of the intervention group received two additional physical education lessons which resulted in a daily physical education lesson. Every physical education lesson of the intervention classes was prepared by a team of expert physical education teachers and included at least 10 min of jumping activities like hopping, jumping up and down stairs, rope skipping etc. The same curriculum was provided to all intervention classes. Ground reaction forces were not measured, but the program has been shown to positively influence the physical activity, aerobic fitness, body fat, a composite cardiovascular risk score(13) as well as bone health(12). Children and parents of the control group were not informed of the existence of the intervention program in other schools. The teachers in the control group knew about the intervention arm, but were not informed about its content. After the intervention period of nine months, the program was ceased and all children, irrespective of group allocation, received for the following years the three compulsory physical education lessons per week given by the normal classroom teachers.

Measurements

Anthropometry and physical activity

Children's height and body mass were measured in T-Shirt, shorts and barefoot using a Harpenden stadiometer (Holtain) with an accuracy of 0.1 cm and an electronic scale (Seca) with an accuracy of 0.1 kg. Body mass index was calculated and transformed into z-scores from published age and gender specific norm values(18). Parents and children were asked to rate children's pubertal stage by a questionnaire with a simple explanation and line drawings of the Tanner stages which has been validated and described as reasonably accurate[19]. Pubertal stage was defined as prepubertal (Tanner stage 1) and pubertal (Tanner stage 2 and above) based on breast development for girls and pubic hair for boys. Migrant status and parental education level was asked by questionnaire and defined as “both parents from Eastern or Southern European countries, Africa, Asia, Central or South America, or other less developed countries” and “no formal parental education”, respectively. Calcium intake was assessed by a validated questionnaire[20], adapted to the Swiss nutrition where daily calcium intake was calculated in milligrams per day. Physical activity was monitored by an accelerometer (MTI/CSA 7164, Actigraph, Shalimar, FL, USA) which was worn continuously around the hip for 7 days. The sampling time was set to 1 min. Based on our pilot work and other reports[21] time periods with over 15 min of continuous zero values were considered to represent periods when the monitors were not worn and were omitted before analyses. An individual child's physical activity data were included if at least three week days and one weekend day of measurements with a minimum of 12 h for week days and 10 h for weekend days were recorded. If not the whole week was measured, data from monitored days were extrapolated to the remaining week by distinguishing week days and weekend days. Physical activity was expressed as average counts min^{-1} (CPM) and vigorous physical activity (VPA) as minutes above 3000 counts min^{-1}[22].

Bone and body composition

Body composition and bone were measured using dual-energy X-ray absorptiometry (DXA; Hologic QDR-4500) located in a truck which travelled to each school. Body composition was assessed by the three compartment model, including fat mass, bone mineral content, and bone mineral free lean tissue. Bone mineral content (BMC, g) and areal bone mineral density (BMD, g/cm^2) were determined for total body, femoral neck, and L1–L4 vertebrae in antero-posterior view. BMC and BMD values were z-transformed using pubertal stage- and gender-specific means and standard deviations derived from the whole sample at each measurement period. The coefficient of variation of repeated measurements for femur, lumbar spine and total body determined in young healthy adults varies between 1–1.6% for BMD, and 0.3–3% for BMC[23].

Statistical Analysis

Statistical analyses were based on the intention-to-treat principle and results are reported at the level of individuals. All children that at least participated at baseline and 3-year follow-up measurements were included into analyses. Prior to the analysis of the intervention’s long term effects, a profound analysis of participating versus non-participating children was made using a multilevel linear regression model with school as the random effect, or using a multilevel logistic regression for binary outcomes, respectively. Explanatory variables for these analyses were participation status (participants vs. non-participants), group allocation (intervention vs. control group) and the interaction term of participation status and group allocation. Analyses were additionally adjusted for gender and grade. Long term effects of the intervention was done using a multilevel linear regression model with the pubertal stage- and gender-specific z-score of BMC, respectively BMD at follow-up as outcome and group, gender, tanner stage at follow-up, baseline height and weight and the respective baseline z-score of the outcome as co-variates. As randomization was made on the level of school, school was introduced as random effect. According to our findings after the nine months of intervention[12], we tested in a second step if the interaction between group and pubertal stage at follow-up modified the effect. In a third step, physical activity was included in the model. For this, the average VPA level of children with at least two physical activity measurements over the 4 year period was included as additional covariate into the model mentioned above. The initial power calculation was performed for the primary outcomes (i.e. physical activity, aerobic fitness, sum of four skinfolds and quality of life) of the study[13]. Due to the radiation exposure, parents and children had to give a special consent for participation in the DXA measurements. Analyses were performed using Stata version 11.0 and the level of significance was set at $p<0.05$.

RESULTS

Participants

A flow with the number of participants is given in Figure 9.1. Of the 502 children participating in the study, 377 (75%) children participated in DXA measurements at baseline. Of those, 114 (77%) of the former first grade children and 100 (44%) of the former fifth grade classes were measured again in the follow-up. Thus, a total of 214 (57%) children could be included into the current analysis. Table 9.1 describes characteristics of the children according to participation and group. The analyses show that participating children did not differ from non-participating children regarding anthropometric characteristics and age. However, among the participants there were significantly more females than males, and fewer children with migrant background. Children were comparable for calcium intake and fat free mass. Participating children showed higher physical activity levels at baseline than their non-participating counterparts. Importantly, there were no differences for all bone outcomes. The participation×group interaction – serving as indication for group differences among participants – showed comparable anthropometric and bone characteristics for all participating children. Solely, physical activity levels differed between groups with lower levels for participating intervention children compared to their counterparts.

Intervention effects at follow-up

Table 9.2 shows the main results of the intervention at follow-up. After adjustment for gender, grade, baseline height and weight, tanner stage at follow-up, baseline BMC and cluster, intervention children showed significantly higher BMC than controls at femoral neck and total hip representing an improvement of 7.1% or 6.6%, respectively. Additionally, there was a tendency towards a higher whole body BMC but no difference for BMC at lumbar spine. Children of the intervention group showed significantly higher adjusted differences at follow-up for whole body BMD, representing an improvement of 5.8% compared to controls. No differences were observed for BMD at femoral neck, total hip and lumbar spine.

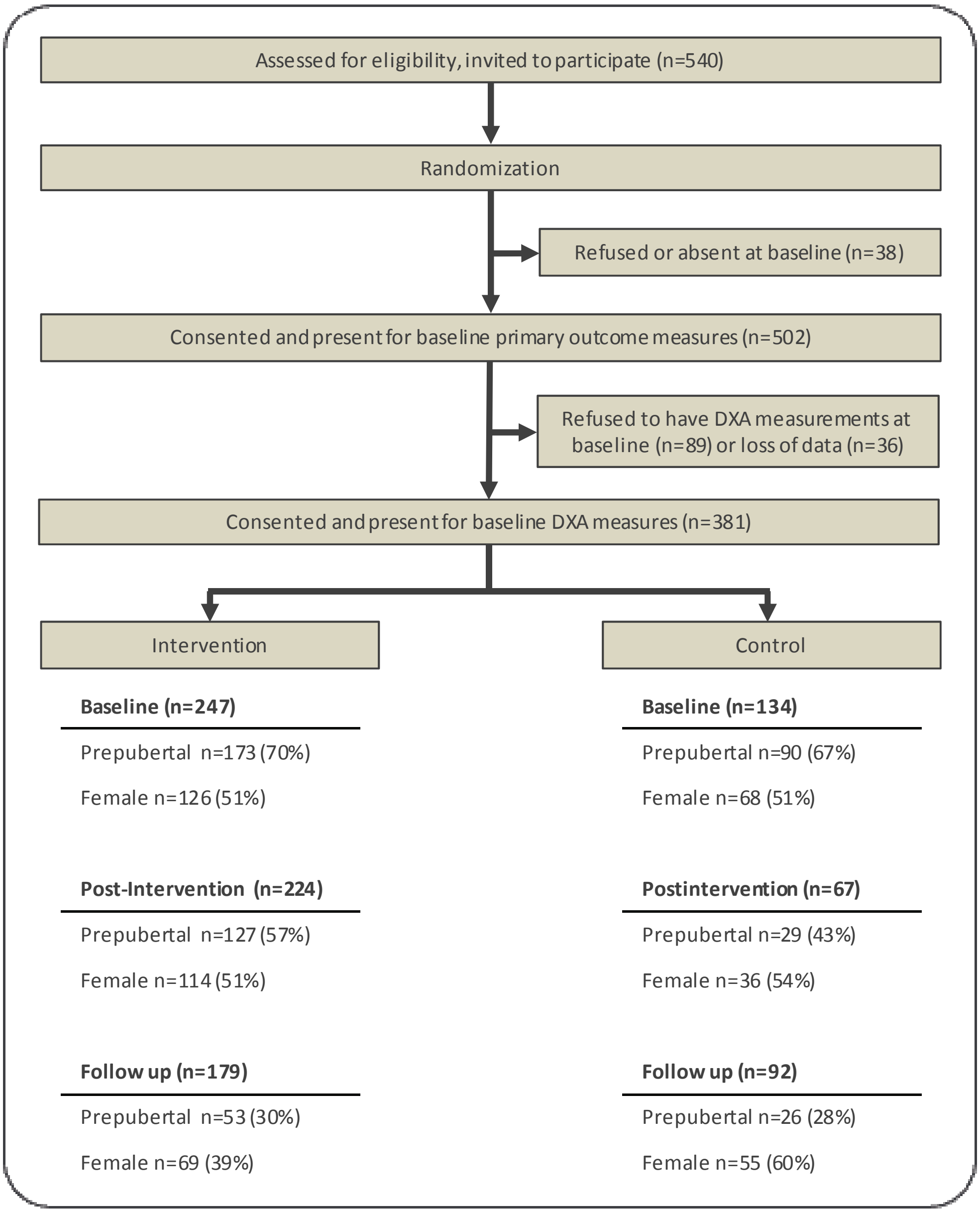

Figure 9.1 Flow sheet of participants through the study.

Table 9.1 Baseline characteristics of children according to treatment arm and participation at follow-up. Values are means (SD) unless stated otherwise.

	Participants				Non-Participants						
	Intervention		Control		Intervention		Control		Baseline differences*		
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	P_{part}	P_{group}	$P_{part*group}$
Age (y)	149	8.8 (2.1)	65	8.8 (2.2)	148	9.6 (2.1)	140	9.2 (2.3)	0.937	0.145	0.517
Height (cm)	149	133.3 (13.1)	65	134.2 (14.2)	141	137.5 (11.8)	128	136.2 (13.8)	0.168	0.874	0.2
Weight (kg)	149	30.7 (8.7)	65	30.4 (9.8)	141	33.5 (9.4)	128	33 (10.3)	0.554	0.718	0.919
BMI (kg/m^2)	149	16.9 (2.2)	65	16.4 (2.4)	141	17.4 (3.0)	128	17.3 (2.6)	0.081	0.968	0.325
Gender, n (%) girls	78 (52%)		40 (62%)		75 (51%)		65 (46%)		0.044	0.486	0.158
Grade, n(%) 1st grade	78 (52%)		36 (55%)		54 (37%)		65 (46%)		0.258	0.562	0.513
n (%) overweights	32 (22%)		10 (15%)		33 (23%)		35 (27%)		0.064	0.468	0.207
n (%) pre-pubertal	116 (78%)		52 (80%)		96 (65%)		102 (73%)		0.138	0.181	0.766
n (%) migrant	32 (22%)		8 (12%)		53 (36%)		48 (34%)		0.002	0.916	0.087
n (%) low parental education	6 (4%)		2 (3%)		25 (19%)		13 (11%)		0.114	0.204	0.718
Calcium Intake (mg/wk)	144	5911 (2471)	62	5796 (3000)	127	6394 (3483)	101	5530 (2487)	0.444	0.116	0.238
Protein Intake (g/(kg*wk))	144	17.86 (9.18)	62	19.01 (10.79)	123	17.8 (10.34)	101	16.6 (9.07)	0.495	0.409	0.31
PA (cpm)	111	734 (187)	49	800 (201)	110	714 (229)	103	725 (210)	0.027	0.333	0.041
PA (MVPA)	111	92.3 (31.4)	49	100.2 (32.3)	110	88.6 (35.4)	103	88.4 (32.8)	0.007	0.348	0.03
PA (VPA)	111	43.1 (21.7)	49	52.2 (21.2)	110	42.8 (23.1)	103	44.8 (22.7)	0.005	0.734	0.013
Bone mineral content											
Total Body (g)	143	732 (222)	65	750 (257)	96	818 (175)	69	898 (260)	0.752	0.002	0.325
Femoral Neck (g)	149	2.33 (0.77)	65	2.39 (0.78)	98	2.67 (0.64)	69	2.88 (0.76)	0.824	0.021	0.653
Total Hip (g)	149	14.37 (5.59)	65	14.72 (5.69)	98	16.63 (4.5)	69	18.63 (6.11)	0.569	0.006	0.199
Lumbar Spine (g)	148	22.26 (6.1)	65	22.99 (7.09)	97	24.8 (5.23)	69	27.44 (8.37)	0.257	0.001	0.171
Bone mineral density											
Total Body (g/cm^2)	143	0.65 (0.1)	65	0.65 (0.11)	96	0.69 (0.08)	69	0.72 (0.1)	0.771	0.002	0.28
Femoral Neck (g/cm^2)	149	0.65 (0.09)	65	0.66 (0.1)	98	0.67 (0.08)	69	0.71 (0.1)	0.773	0.011	0.473
Total Hip (g/cm^2)	149	0.68 (0.09)	65	0.69 (0.1)	98	0.7 (0.08)	69	0.74 (0.12)	0.727	0.011	0.211
Lumbar Spine (g/cm^2)	148	0.59 (0.1)	65	0.6 (0.11)	97	0.62 (0.08)	69	0.65 (0.11)	0.499	0.134	0.341

*Regression or logistic regression analyses were done based on age-group and gender based z-scores to compare data for group, participation and group*participation differences after adjustment for cluster (school).
BMI, body mass index; PA, physical activity; cpm, counts per minute; MVPA, moderate-and-vigorous physical activity; VPA, vigorous physical activity.

The interaction term group×pubertal stage did not have a significant effect on the model for any BMC and BMD parameters, indicating that there were no differences in the maintenance of response to the intervention program between pubertal and pre-pubertal children. After inclusion of VPA, all intervention effects disappeared with adjusted differences for BMC at femoral neck and total hip of 0.135 (-0.140 – 0.410; p=0.335) and 0.166 (-0.078 – 0.409; p=0.182) z-score units, respectively. And an adjusted group difference in whole body BMD at follow-up of 0.082 (-0.119 – 0.282; p=0.424).

Table 9.2 3-year follow-up effects of a nine months physical activity intervention on bone mineral content and density. Values at baseline and follow-up are means (SD).

	Intervention		Control		Adjusted difference at follow-up*	
Variables	Before	At follow-up	Before	At follow-up	Coefficient (95% CI)	P value
Bone mineral content						
Total Body (g)	731.7 (222.5)	1196.0 (458.0)	749.9 (256.8)	1153.3 (424.4)	0.137 (-0.004 - 0.278)	0.056
Femoral Neck (g)	2.33 (0.77)	3.67 (1.03)	2.39 (0.78)	3.54 (0.92)	0.180 (0.007 - 0.354)	0.042
Total Hip (g)	14.37 (5.59)	24.98 (10.8)	14.72 (5.69)	23.53 (8.37)	0.167 (0.014 - 0.320)	0.032
Lumbar Spine (g)	22.26 (6.1)	39.07 (16.09)	22.99 (7.09)	37.86 (14.99)	0.100 (-0.053 - 0.253)	0.201
Bone mineral density						
Total Body (g/cm^2)	0.649 (0.096)	0.794 (0.128)	0.654 (0.109)	0.781 (0.127)	0.145 (0.015 - 0.276)	0.028
Femoral Neck (g/cm^2)	0.647 (0.087)	0.775 (0.123)	0.659 (0.101)	0.781 (0.137)	0.036 (-0.118 - 0.189)	0.650
Total Hip (g/cm^2)	0.681 (0.094)	0.834 (0.149)	0.687 (0.103)	0.827 (0.144)	0.038 (-0.167 - 0.243)	0.718
Lumbar Spine (g/cm^2)	0.588 (0.097)	0.782 (0.165)	0.596 (0.11)	0.774 (0.173)	0.044 (-0.113 - 0.201)	0.584

*Adjusted difference in average z-score of respective outcome at follow-up between intervention and control group with 95% confidence interval and p value, adjusted for sex, grade, baseline weight, baseline height, pubertal stage at follow-up and z-score of baseline bone mineral content/density, and school as cluster.

DISCUSSION

This randomized controlled trial showed that positive intervention effects on bone mineral of a general school-based physical activity intervention over one school-year in pre- and early pubertal children(12) were partially maintained three years after the program had stopped. This intervention was from a public health perspective most important as it showed that multiple beneficial effects positively affecting body composition, aerobic fitness, physical activity and cardiovascular risk(13) but also bone health could be attained by the same school-based physical activity program.

Three years after the intervention, maintained effects could be observed in BMC at weight-bearing sites (i.e. femoral neck and total hip). At follow-up, children of the intervention group showed still 7.1% higher femoral neck BMC and 6.6% higher total hip BMC compared to controls. Yet, obtained post-intervention benefits for whole body and lumbar spine BMC, as well as for most BMD levels have diminished over the three years. Maximizing peak bone mass during the growing years is recognized as an essential strategy for preventing osteoporosis later in life(2) and it has been shown that the years around puberty are a crucial period for the accrual of bone mass(24). Especially pre- and early puberty represents an ideal “window of opportunity” to intervene, for instance with an exercise program[25-27]. However, an exercise intervention is only worthwhile if the obtained beneficial effects persist over time. To our knowledge this is the first randomized controlled trial showing that a general school-based physical activity program over nine months in pre- and early pubertal children may have sustained effects on bone mineral content at weight-bearing sites over three years. From a public health perspective the reach of different health outcomes with the same program is without any doubt much more attractive than a tailored jumping intervention to focus only on bone health.

Long-term effects from tailored intervention studies showed beneficial effects up to eight years after the intervention. Data from an 8-year follow-up of a school-based randomized controlled trial in 7-8 years old children including a tailored jumping program over seven months[15] showed sustained effects on total hip BMC. However, the relative contribution of the intervention effect decreased over the years from 3.6% at post-intervention to 1.4% after eight years. These results could be confirmed in a second study population that followed a similar intervention program[16]. Four years after a seven months lasting jumping program in 8-9 years old children, intervention children still had 2.3-4.4% higher BMC compared to controls at lumbar spine, total hip, femoral neck and whole body. However, since these differences as well tended to diminish over the years, it still remains unclear whether even a tailored jumping program can induce sustained benefits on BMC that last into adulthood. In a properly designed study in animals, Warden et al.[28] followed rats after a short-term exercise program to investigate whether exercise during growth results in lifelong benefits in bone quantity and structure. While exercise-induced benefits in BMC and BMD did not persist after detraining, benefits in bone structure and strength were maintained lifelong. Thus, the loss of beneficial effects on BMC after cessation of the program does not necessarily mean that there is no maintained effect on bone strength. Bone strength is determined by both, bone quantity and bone structure[29]. Animal studies have showed that mechanical loading derived from weight-bearing exercise generated increases in bone strength without substantial increases in bone quality. And these structural changes of bone persisted into adulthood while loading-induced changes in bone mass diminished over time[30, 31].

At the end of the intervention, short-time benefits could be observed at both, weight-bearing and non-weight-bearing sites[12]. However, three years after cessation of the program, solely intervention effects at weight-bearing sites (i.e. femoral neck and total hip) were maintained. As the response of bone to loading is highly stimulus-specific[32] and if appropriate resulting in a site-specific adaptation, only bones that are loaded sufficiently undergo adaptation. This could be shown elegantly in racket sport players by comparing dominant and non-dominant forearm bones. Thereby, reported differences varied between 2-20%[27, 33-35] with greater differences in children who started playing before puberty. Children’s physical activity levels at follow-up were by trend higher for average physical activity, but not for moderate-and-vigorous physical activity among groups[36]. This could explain why BMC levels of intervention children were still significantly enhanced at weight-bearing sites of the skeleton, where physical activity acts most. The fact that with the adjustment of the children's actual time spent in vigorous physical activity, all intervention effects at follow-up disappeared, strongly suggest that the maintained benefits resulted from maintained (even though not significant) physical activity levels of intervention children.

The scientific world agrees that we have much more reliable information about the effects of physical activity on bone since physical activity is measured objectively by accelerometers, especially in children who are not able to report their behavior accurately[37]. The use of accelerometers provides us with a much clearer picture of how often bone was loaded and by what intensity that when assessed by questionnaires. Accelerometers generally measure physical activity over a week and importantly over a predefined measurement window that has been usually done over a sampling interval of one minute in relevant studies[38]. This means, that the single vertical accelerations of the body were first converted into a positive direction and then integrated over the sampling interval[39] – in our case over one minute. We know from animal models that just a few very high accelerations of the body may suffice to stimulate bone sufficiently[40, 41]. Yet, they may not be detectable by our accelerometer assessment due to the smoothing of the raw accelerations. In other words, if a child jumps 10 times over 2 minutes from a table of 70 cm height, it may have done osteogenic impact loading that however, might not be detected by a high level of vigorous physical activity due to the smoothing of the single accelerations of a fractional amount of a second over one minute. Furthermore, the actual cut-offs that have been defined for vigorous physical activity are based on metabolic equivalents describing cardiometabolic intensity rather than on true accelerations as would be adequate to measure impact on bones. Future studies have to be done to validate accelerometers for impact loading of the bone, thereby facing the existing limitations of metabolic cut-offs, arbitrary units of counts that are not well defined, and the smoothing of the raw accelerations.

Whereas short-term effects of our intervention program showed significant benefits on BMC and on BMD[12], long-term effects could only be observed for BMC. The interpretation of BMD in the growing skeleton is much more challenging than in adults. Measured by DXA, BMD represents an areal rather than a true volumetric density. Thus, the true depth of bone is not taken into account. In DXA scans, larger bones produce higher BMC and (areal) BMD values even if they do not have higher volumetric density[42]. This size-dependence is of particular relevance in the three-dimensional growth of children. Consequently, bone mineral mass or content rather than density might be more suitable to understand the effects of exercise on bone health during the growing years[43]. Further, it has been shown that bone area and mineralization do not develop simultaneously[24] which further complicates the interpretation of BMD.

Our study has significant strengths and some potential limitations. Besides being a randomized controlled trial, strengths of the study are that the intervention was conducted in a representative sample of pre- and early pubertal children. Since the physical activity program was integrated into the school curriculum, compliance of the program was given. From a public health perspective the short-term effects of the program on general health have been promising[13] and even three years after cessation of the program, enhanced aerobic fitness levels in children of the intervention group are still observable[36]. However, several limitations have to be acknowledged. Due to the low participation rate at follow-up, it is debatable whether our study population is still representative. We therefore scrutinized carefully whether differences between participants and non-participants existed. Especially older males, and children with a migrant background have dropped out which may reduce generalizibility due to a selection bias. The lack of significant interaction between participating and group, at least ensures that the composition of children participating were comparable in both groups. It has to be mentioned here, that we have done everything possible to address as many children as possible. We have offered multiple test dates including time windows during school time at the children's schools and provided them gift vouchers for participating (25 and 40 Euros for the younger and older children, respectively). The level of drop-out is comparable to time-wise comparable follow-up periods of school-based interventions[16], but still better than long-term follow-ups of extended time windows[15]. This is a common problem in studying long-term effects of trials. This problem should therefore be considered in the initial power analysis, especially when adolescents with their low compliance should be included. On a methodological level, limitations of DXA have to be addressed. While DXA provides a reasonable picture of overall bone quantity, it is unable to assess bone's structure and architecture. As structural adaptations occur even without substantial increases in bone mineral content[30, 31], the short- and long-term effects of interventions on bone mineral content plausibly underestimate the real effect on bone strength. Due to the two-dimensional assessment of BMD by DXA, an interpretation particularly in the growing skeleton of children has to be done cautiously[42]. The problem can somehow be reduced by the use of sex- and pubertal stage-adjusted z-scores and the adjustment of the statistical models for children's body height and mass. First publications of new radiological approaches that look at microstructure of distal tibia and radius look promising[44, 45], although the problem of longitudinally comparable measure sites in growing bones is not yet solved[46, 47].

The original sampling frame included 10% of the population of two provinces of Switzerland and included rural and urban areas with a migrant population of 10-30% which is representative for Switzerland and also for central Europe. However, differences between school systems in different countries might have an impact on findings, requiring specific research. Our intervention program was implemented into the normal school curriculum and was therefore mandatory which guaranteed compliance of all children. Compliance of teachers and children were not measured. The fact that 90% of children and 70% of teachers liked the program and wished that it would continue implies that even if the program was stringent and mandatory, such a change of school environment even on a longer term might be a promising strategy. The key process is now to find effective implementation strategies to transfer this physical activity program into the real-life setting.

A 10% increase in peak bone mass was calculated to delay the onset of osteoporosis by 13 years(48) and reduce the osteoporotic fracture risk by up to 50% in women after menopause(49). Compared to controls, children in the intervention group showed still 6.6-7.1% higher BMC at femoral neck and total hip three years after cessation of the intervention, notably at the site where the most severe osteoporotic fractures occur(50). However, it remains unclear, whether these effects persist until peak bone mass is reached and whether structural adaptation that are not detectable by DXA may have occurred in concert. Further intervention studies with longer follow-up periods, larger sample sizes, with the inclusion of more accurate assessment of osteogenic physical activity and more sophisticated techniques to detect structural adaptations of bone by mechanical loading are needed to address this issue more thoroughly.

REFERENCES

(1) Hui SL, Slemenda CW, Johnston CC, Jr. The Contribution of Bone Loss to Postmenopausal Osteoporosis. Osteoporos Int. 1990; 1(1): 30.

(2) Rizzoli R, Bianchi ML, Garabedian M, McKay HA, Moreno LA. Maximizing Bone Mineral Mass Gain During Growth for the Prevention of Fractures in the Adolescents and the Elderly. Bone. 2010; 46(2): 294.

(3) Bonjour JP, Chevalley T, Rizzoli R, Ferrari S. Gene-Environment Interactions in the Skeletal Response to Nutrition and Exercise During Growth. Med Sport Sci. 2007; 51: 64.

(4) Davies JH, Evans BA, Gregory JW. Bone Mass Acquisition in Healthy Children. Arch Dis Child. 2005; 90(4): 373.

(5) Hopper JL, Green RM, Nowson CA, Young D, Sherwin AJ, Kaymakci B, et al. Genetic, Common Environment, and Individual Specific Components of Variance for Bone Mineral Density in 10- to 26-Year-Old Females: A Twin Study. Am J Epidemiol. 1998; 147(1): 17.

(6) Forwood MR. Physical Activity and Bone Development During Childhood: Insights from Animal Models. J Appl Physiol. 2008; 105(1): 334.

(7) Hind K, Burrows M. Weight-Bearing Exercise and Bone Mineral Accrual in Children and Adolescents: A Review of Controlled Trials. Bone. 2007; 40(1): 14.

(8) Gunter KB, Almstedt HC, Janz KF. Physical Activity in Childhood May Be the Key to Optimizing Lifespan Skeletal Health. Exerc Sport Sci Rev. 2011.

(9) Nikander R, Sievanen H, Heinonen A, Daly RM, Uusi-Rasi K, Kannus P. Targeted Exercise against Osteoporosis: A Systematic Review and Meta-Analysis for Optimising Bone Strength Throughout Life. BMC Med. 2010; 8: 47.

(10) McKay HA, MacLean L, Petit M, MacKelvie-O'Brien K, Janssen P, Beck T, et al. "Bounce at the Bell": A Novel Program of Short Bouts of Exercise Improves Proximal Femur Bone Mass in Early Pubertal Children. Br J Sports Med. 2005; 39(8): 521.

(11) Fuchs RK, Bauer JJ, Snow CM. Jumping Improves Hip and Lumbar Spine Bone Mass in Prepubescent Children: A Randomized Controlled Trial. J Bone Miner Res. 2001; 16(1): 148.

(12) Meyer U, Romann M, Zahner L, Schindler C, Puder JJ, Kraenzlin M, et al. Effect of a General School-Based Physical Activity Intervention on Bone Mineral Content and Density: A Cluster-Randomized Controlled Trial. Bone. 2011; 48(4): 792.

(13) Kriemler S, Zahner L, Schindler C, Meyer U, Hartmann T, Hebestreit H, et al. Effect of School Based Physical Activity Programme (Kiss) on Fitness and Adiposity in Primary Schoolchildren: Cluster Randomised Controlled Trial. Br Med J. 2010; 340(feb23 1): c785.

(14) Baxter-Jones AD, Kontulainen SA, Faulkner RA, Bailey DA. A Longitudinal Study of the Relationship of Physical Activity to Bone Mineral Accrual from Adolescence to Young Adulthood. Bone. 2008; 43(6): 1101.

(15) Gunter K, Baxter-Jones AD, Mirwald RL, Almstedt H, Fuchs RK, Durski S, et al. Impact Exercise Increases Bmc During Growth: An 8-Year Longitudinal Study. J Bone Miner Res. 2008; 23(7): 986.

(16) Gunter K, Baxter-Jones AD, Mirwald RL, Almstedt H, Fuller A, Durski S, et al. Jump Starting Skeletal Health: A 4-Year Longitudinal Study Assessing the Effects of Jumping on Skeletal Development in Pre and Circum Pubertal Children. Bone. 2008; 42(4): 710.

(17) Zahner L, Puder JJ, Roth R, Schmid M, Guldimann R, Puhse U, et al. A School-Based Physical Activity Program to Improve Health and Fitness in Children Aged 6-13 Years ("Kinder-Sportstudie Kiss"): Study Design of a Randomized Controlled Trial [Isrctn15360785]. BMC Public Health. 2006; 6: 147.

(18) de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a Who Growth Reference for School-Aged Children and Adolescents. Bull World Health Organ. 2007; 85(9): 660.

(19) Duke PM, Litt IF, Gross RT. Adolescents' Self-Assessment of Sexual Maturation. Pediatrics. 1980; 66(6): 918.

(20) Molgaard C, Sandstrom B, Michaelsen KF. Evaluation of a Food Frequency Questionnaire for Assessing of Calcium, Protein and Phosphorus Intakes in Children and Adolescents. Scand J Nutr. 1998; 42(1): 2.

(21) Andersen LB, Harro M, Sardinha LB, Froberg K, Ekelund U, Brage S, et al. Physical Activity and Clustered Cardiovascular Risk in Children: A Cross-Sectional Study (the European Youth Heart Study). Lancet. 2006; 368(9532): 299.

(22) Ekelund U, Sardinha LB, Anderssen SA, Harro M, Franks PW, Brage S, et al. Associations between Objectively Assessed Physical Activity and Indicators of Body Fatness in 9- to 10-Y-Old European Children: A Population-Based Study from 4 Distinct Regions in Europe (the European Youth Heart Study). Am J Clin Nutr. 2004; 80(3): 584.

(23) Bonjour JP, Chevalley T, Ammann P, Slosman D, Rizzoli R. Gain in Bone Mineral Mass in Prepubertal Girls 3.5 Years after Discontinuation of Calcium Supplementation: A Follow-up Study. Lancet. 2001; 358(9289): 1208.

(24) Baxter-Jones AD, Faulkner RA, Forwood MR, Mirwald RL, Bailey DA. Bone Mineral Accrual from 8 to 30 Years of Age: An Estimation of Peak Bone Mass. J Bone Miner Res. 2011; 26(8): 1729.

(25) Hughes JM, Novotny SA, Wetzsteon RJ, Petit MA. Lessons Learned from School-Based Skeletal Loading Intervention Trials: Putting Research into Practice. Med Sport Sci. 2007; 51: 137.

(26) MacKelvie KJ, Khan KM, McKay HA. Is There a Critical Period for Bone Response to Weight-Bearing Exercise in Children and Adolescents? A Systematic Review. Br J Sports Med. 2002; 36(4): 250.
(27) Bass SL, Saxon L, Daly RM, Turner CH, Robling AG, Seeman E, et al. The Effect of Mechanical Loading on the Size and Shape of Bone in Pre-, Peri-, and Postpubertal Girls: A Study in Tennis Players. J Bone Miner Res. 2002; 17(12): 2274.
(28) Warden SJ, Fuchs RK, Castillo AB, Nelson IR, Turner CH. Exercise When Young Provides Lifelong Benefits to Bone Structure and Strength. J Bone Miner Res. 2007; 22(2): 251.
(29) Kontulainen SA, Hughes JM, Macdonald HM, Johnston JD. The Biomechanical Basis of Bone Strength Development During Growth. Med Sport Sci. 2007; 51: 13.
(30) Robling AG, Hinant FM, Burr DB, Turner CH. Improved Bone Structure and Strength after Long-Term Mechanical Loading Is Greatest If Loading Is Separated into Short Bouts. J Bone Miner Res. 2002; 17(8): 1545.
(31) Warden SJ, Hurst JA, Sanders MS, Turner CH, Burr DB, Li J. Bone Adaptation to a Mechanical Loading Program Significantly Increases Skeletal Fatigue Resistance. J Bone Miner Res. 2005; 20(5): 809.
(32) Warden SJ. Breaking the Rules for Bone Adaptation to Mechanical Loading. J Appl Physiol. 2006; 100(5): 1441.
(33) Kontulainen S, Sievanen H, Kannus P, Pasanen M, Vuori I. Effect of Long-Term Impact-Loading on Mass, Size, and Estimated Strength of Humerus and Radius of Female Racquet-Sports Players: A Peripheral Quantitative Computed Tomography Study between Young and Old Starters and Controls. J Bone Miner Res. 2003; 18(2): 352.
(34) Ducher G, Daly RM, Bass SL. Effects of Repetitive Loading on Bone Mass and Geometry in Young Male Tennis Players: A Quantitative Study Using Mri. J Bone Miner Res. 2009; 24(10): 1686.
(35) Ducher G, Bass SL, Saxon L, Daly RM. Effects of Repetitive Loading on the Growth-Induced Changes in Bone Mass and Cortical Bone Geometry: A 12-Month Study in Pre/Peri- and Postmenarcheal Tennis Players. J Bone Miner Res. 2011; 26(6): 1321.
(36) Meyer U, Schindler C, Zahner L, Ernst D, Probst-Hensch N, Hebestreit H, et al. Long-Term Effect of a School-Based Physical Activity Program (Kiss) on Fitness and Adiposity in Primary School Children: A Randomized Controlled Trial. In submission.
(37) Sallis JF. Self-Report Measures of Children's Physical Activity. J Sch Health. 1991; 61: 215.
(38) Janz KF, Gilmore JM, Levy SM, Letuchy EM, Burns TL, Beck TJ. Physical Activity and Femoral Neck Bone Strength During Childhood: The Iowa Bone Development Study. Bone. 2007; 41(2): 216.
(39) Chen KY, Bassett DR, Jr. The Technology of Accelerometry-Based Activity Monitors: Current and Future. Med Sci Sports Exerc. 2005; 37(11 Suppl): S490.
(40) Rubin CT, Lanyon LE. Regulation of Bone Formation by Applied Dynamic Loads. J Bone Joint Surg Am. 1984; 66(3): 397.
(41) Rubin CT, Lanyon LE. Regulation of Bone Mass by Mechanical Strain Magnitude. Calcif Tissue Int. 1985; 37(4): 411.
(42) van Rijn RR, Van Kuijk C. Of Small Bones and Big Mistakes; Bone Densitometry in Children Revisited. Eur J Radiol. 2009; 71(3): 432.
(43) Parfitt AM. The Two Faces of Growth: Benefits and Risks to Bone Integrity. Osteoporos Int. 1994; 4(6): 382.
(44) Kirmani S, Christen D, van Lenthe GH, Fischer PR, Bouxsein ML, McCready LK, et al. Bone Structure at the Distal Radius During Adolescent Growth. J Bone Miner Res. 2009; 24(6): 1033.
(45) McKay H, Liu D, Egeli D, Boyd S, Burrows M. Physical Activity Positively Predicts Bone Architecture and Bone Strength in Adolescent Males and Females. Acta Paediatr. 2011; 100(1): 97.
(46) Zemel B, Bass S, Binkley T, Ducher G, Macdonald H, McKay H, et al. Peripheral Quantitative Computed Tomography in Children and Adolescents: The 2007 Iscd Pediatric Official Positions. J Clin Densitom. 2008; 11(1): 59.
(47) Zemel BS. Quantitative Computed Tomography and Computed Tomography in Children. Curr Osteoporos Rep. 2011; 9(4): 284.
(48) Hernandez CJ, Beaupre GS, Carter DR. A Theoretical Analysis of the Relative Influences of Peak Bmd, Age-Related Bone Loss and Menopause on the Development of Osteoporosis. Osteoporos Int. 2003; 14(10): 843.
(49) Marshall D, Johnell O, Wedel H. Meta-Analysis of How Well Measures of Bone Mineral Density Predict Occurrence of Osteoporotic Fractures. Br Med J. 1996; 312(7041): 1254.
(50) Johnell O, Kanis J. Epidemiology of Osteoporotic Fractures. Osteoporos Int. 2005; 16 Suppl 2: S3.

CHAPTER 10

Synthesis, Discussion & Perspectives

SYNTHESIS, DISCUSSION & PERSPECTIVES

Based on the aims outlined in Chapter 3, the following first section summarizes the main results of this dissertation. Because the specific findings have been discussed in detail in the respective articles, more general aspects of the main findings will be described in a broader scientific context and beyond the puristic approach taken in peer-reviewed journals. Last, I will finish up by providing an outlook with inclusion of research gaps that may be tackled in the future.

SUMMARY OF THE MAIN RESULTS

Aim 1. To identify and summarize existing reviews of school-based physical activity interventions and to carry out a systematic review of recent intervention studies and prospectively verify predefined factors that may play a role for a positive outcome. (Chapter 4)

Four recent and comprehensive review articles covering school-based physical activity interventions have been identified. While all of the reviews reported generally positive impacts on physical activity levels, a clear picture of effective intervention strategies was still missing. All trials in the systematic update reported significant intervention effects in at least one domain of physical activity (in-school, out-of-school, overall). Thereby, the most successful interventions had the design of a randomized controlled trial, were done in children (rather than adolescents), lasting over one school year using a multi-component approach integrated into the school curriculum, taught by physical education experts and involving family members. Despite the positive picture, there was an overall lack of long-term follow-ups and of effective implementation strategies.

Aim 2. To assess physical activity during regular physical education in randomly selected primary school children and to determine to what degree physical education contributes to overall physical activity. (Chapter 5)

Accelerometer data from a representative sample of 676 first and fifth grade school children showed that children spent about one third of their physical education time in moderate and vigorous physical activity, corresponding to an average of 17 minutes per lesson of 45 minutes. Comparing days with and days without physical education, children were significantly more active on days with physical education. Thereby the additional activity on days with physical education was about the same amount of physical activity that children spent during their physical education lesson. Thus, additional physical activity was not compensated by reducing out-of-school physical activity. We therefore conclude that although physical activity levels during physical education were low, physical education played a considerable role in providing health-enhancing physical activity.

Aim 3. To assess the effectiveness of a general school-based physical activity program (KISS) during one school-year on fitness, body fat, physical activity, quality of life and cardiovascular risk in young schoolchildren. (Chapter 6)

Aim 4. To explore whether this physical activity intervention program (KISS) was sufficient for these positive fitness and health outcomes to persist over three years. (Chapter 7)

A stringent, multi-component physical activity program including a daily physical education lesson, several daily short activity breaks, and physical activity homework was conducted over one school year in 16 first and fifth grade classes (n=297 children). Compared to children in the control classes (12 classes, n=205 children), the intervention children showed smaller increases in skinfolds thickness and body mass index, an increase in aerobic fitness, higher physical activity levels (in school and overall) and a decreased cardiovascular risk score. After one school year, the program was stopped and children continued to receive the normal curriculum including three physical education lessons per week. Three years after cessation, 59% of all children were measured again. While the beneficial effects on body composition and cardiovascular risk had disappeared, children in the intervention compared to the control group still had significantly higher aerobic fitness levels and a trend towards higher overall physical activity levels. This indicates that a continuous intervention seems necessary to maintain overall beneficial health effects as reached while intervening, but even if this is not possible, persistent effects on aerobic fitness make this intervention worthwhile.

Aim 5. To determine whether a general physical activity intervention program aiming at improving multiple health outcomes (KISS) increases bone mineral content and bone mineral density in children. (Chapter 8)

Aim 6. To investigate whether the beneficial intervention effects on bone health were maintained three years after the program had ceased. (Chapter 9)

Bone mineral content and bone mineral density were assessed by dual energy X-ray absorptiometry (DXA) at baseline and after nine month of intervention in 291 (58%) children participating in the study. Compared to control group, children of the intervention group showed significantly higher increases in bone mineral content of whole body, femoral neck and lumbar spine, and bone mineral density of whole body and lumbar spine. Three years after cessation of the program, bone parameters were measured again in 214 (43%) children. Whereas beneficial intervention effects on non-weight-bearing sites (i.e. lumbar spine) had disappeared, beneficial effects in favor of the intervention group still existed at weight-bearing sites (i.e. femoral neck), where physical activity acts most. Even though these findings are promising, prolonged follow-up periods are required in order to address whether these effects persist into late adolescence or adulthood.

GENERELL DISCUSSION

Long-term effects of the KISS

Our findings of the systematic review update indicated, that even if there is strong evidence for a positive effect of school-based interventions on physical activity in children, there is a striking lack of knowledge concerning long-term effects of intervention studies. Addressing this issue, we did a follow-up measurement three years after the program had stopped.

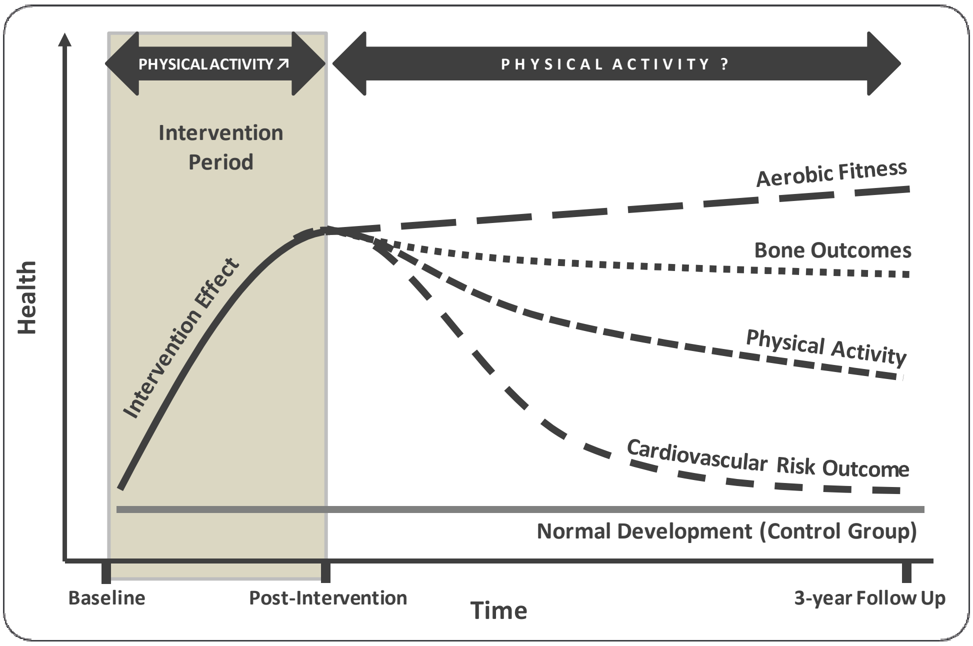

Figure 10.1 Schematic diagram of outcome development

Figure 10.1 shows a schematic diagram of how health outcomes have developed after cessation of the intervention. At follow-up, children of the intervention group showed persisting increases in aerobic fitness and specific parameters of bone mass. All other beneficial effects of the intervention (i.e. cardiovascular risk outcomes including factors of the metabolic syndrome and body fat) had disappeared over the period of three years. Ideally and depending on the extent of behavioral change, the benefits would have been maintained or even further increased. However, it seems that an intervention over one school year is only partly sufficient at maintaining health benefits or associated behavioral changes.

Whereas cardiovascular risk, bone health and aerobic fitness are more or less stable parameters representing the lifestyle effects during recent weeks, months or years, physical activity is more a behavioral factor that is much more variable within individuals. By measuring physical activity over several days, we tried to assess a habitual pattern of a child's physical activity; however, it remains a short-term snapshot of current behavior. Interpreting the role of physical activity as merely a means to the end of several health outcomes, it would be interesting to know how physical activity levels have been during the 3-year period between post-intervention and follow-up. Since we did not measure physical activity in this time period, we can only speculatively address this issue. Based on the fact that aerobic fitness was still enhanced at follow-up or possibly even further increased compared to controls, one can assume that intervention children have maintained a fitness-relevant amount of physical activity during this time period. The maintained aerobic fitness is a major finding, since aerobic fitness is an important protective factor against cardiovascular disease in adults[1-4]. It has also been shown that high aerobic fitness levels during youth are associated with a better cardiovascular risk profile in adulthood[5-7]. While the beneficial effects of regular physical activity on cardiovascular risk factors are well documented[8-10], little is known how these factors respond to a cessation of an exercise program. Assumptions and explanations might derive from detraining studies in which regularly exercising participants are followed for a period with an insufficient training stimulus[11] that is thought to lead to a partial or complete loss of training-induced adaptations[11]. Both, in highly trained and recently trained adults, longer periods of inactivity resulted in a complete reversal of exercise-induced aerobic fitness gains (VO_2max and endurance performance)[12]. Similar effects could be observed for blood lipid levels of young women after a detraining period; already six weeks after a 16 weeks period of aerobic training, beneficial effects on triglycerides and high-density lipoprotein-cholesterol have disappeared[13]. However, detraining studies are often performed in a selective population of trained athletes or obese adults and with short training and detraining periods, thus the transferability to normally trained, healthy children might be restricted. Nevertheless, the fact, that beneficial effects in aerobic fitness and blood lipids are lost already after a short duration of detraining even though in a highly selective population supports our hypothesis that physical activity levels were sufficiently high during the three years after the intervention to maintain or even raise fitness levels of the children in the intervention group.

The fact that beneficial effects in specific bone parameters were observed is another promising finding. Loading studies in animals showed that already small increases (<10%) in bone mass generated large increases (>60%) in bone mechanical properties[14, 15]. The efficient architectural bone response might be explained by the new bone tissue being placed at locations where mechanical demands are greatest. During growth, exercise induced new bone mass is predominately accumulated at the periosteal (outer) surface of bone[16] which improves mechanical strength of a bone more than what would be expected from bone mineral accrual alone[14]. Thus, exercise leads more to a structural optimization without excessively increasing overall weight of the skeleton[17]. Moreover, in contrast to simple bone mineral accrual, structural adaptations are more likely to persist into adulthood[18, 19]. What exactly happens to the growing skeleton if exposed to exercise is still a matter of debate mainly due to the unresolved problems of insufficient measurement tools that precisely measure tissue properties and architectural changes and the still undefined interaction of growth and exercise. Yet, follow-up results of randomized controlled trials in children showed that benefits in bone mineral content, even though decreasing over time, could be maintained over several years[20, 21]. In our study, benefits in bone mineral content were maintained at weight-bearing sites (i.e. femoral neck and total hip); while effects at lumbar spine and for whole body have already diminished over the three years supporting the established principle of exercise-related specific loading that was at least partly maintained.

Only a few school-based physical activity programs have looked at the maintenance of positive health effects after the interventions had ceased (Table 10.1). All of these long-term follow-up studies have shown some persisting positive health effects 2 to 20 years after cessation of the intervention programs. These persisting effects were most consistent for physical activity parameters, and single persisting effects could be measured for body mass index, some fitness components or for single cardiovascular risk factors. However, although the overall effects sometimes remained statistically significant, they tended to disappear over time. As most of these studies showed methodological limitations such as lack of randomization (Cretan Heath and Nutrition Education Program[22-25], Oslo Youth Study[26-28], Trois-Rivières Study[29-32]), the assessment of physical activity only at school (SPARK[33-35]) or by self-report questionnaires (CATCH[36-40], SPARK[33-35], Cretan Heath and Nutrition Education Program[22-25], Oslo Youth Study[26-28], Trois-Rivières Study[29-32]), body mass index as single measure of body composition (Switch[41], Switch-Play[42]), or no assessment of cardiovascular risk factors and/or bone health. Considering that until now many intervention studies have been performed, there is a surprising lack of well-designed long-term follow-ups. KISS adds novel data to this paucity by using objective assessment methods for physical activity, by measuring body composition not only by body mass index, and by assessing all major cardiovascular risk factors including in the metabolic syndrome and bone mineral content and density.

Table 10.1 Long term effects of school-based physical activity intervention studies

Description of the Intervention				Outcomes					Results		Participation rate at Follow-up
Study References Location	Design Subjects Age	Intervention	Duration of Intervention and Follow-up	Body fat	Aerobic Fitness	Physical activity	Cardio-vascular Risk	Bone Health	Intervention	Follow up	
BUGSY([21]) **Building Growing Skeletons in Youth** USA	RCT N=205, Int=1sch, Con=1sch 8-10	Jumping program during PE, 3x 20min/wk	I=7mt FU=3y					DXA	BMC↑	BMC↑	55%
BUGSY[20, 43] **Building Growing Skeletons in Youth** USA	RCT N=89 7-9	Jumping program during PE, 3x 20min/wk	I=7mt FU1=7mt FU2=8y					DXA	BMC↑	BMC↑	47%
CATCH[36-40] **Child and Adolescent Trial for Cardiovascu-lar Health** USA	RCT N=5106, Int=56sch, Con=40sch 8-10	PE change, health edu, food service modification, family reinforce-ments	I=3y FU=3y	BMI, SF	9-min run	SR, obs during PE	BP, lipids		MVPA↑ in PE, PA↑ out of school, no effect on CVR, Body fat, Fitness	VPA↑, no effect on TPA, Body fat, CVR	73%
Cretan Heath and Nutrition Education Program[22-25] Crete	CT N=1046, Int=24sch, Con=16sch 6-12	Edu in PA (4-6h per y), D and health (13-17h per y)	I=6y FU=4y	BMI, SF	20m-shuttle run	SR	BP, lipids		BMI↓, MVPA↑, Fitness↑, CVR↓	BMI↓, MVPA↑ in boys, not in girls, CVR↓, no effect on Fitness	61%
Oslo Youth Study[26-28] Norway	CT N=562, Int=3sch, Con=3sch 10-14	Edu in PA	I=2y FU=8y			SR			VPA↑ in boys	PA↑ in boys	75%
SPARK[33-35] **Sports, Play, and Active Recreation for Kids** USA	RCT N=955, Int1=2sch, Int2=2sch, Con=3Sch 9-10	Int1=PE Specialists (PES), Int2=trained teacher (TT)	I=3y FU=1.5y			SR, obs during PE			MVPA in PE↑, no effect on PA outside school	TT maintained MVPA, with-drawal of PES reduced PE to control levels	Con not in-cluded in follow-up
Switch-Play[42] Australia	RCT N=295, Int/Con=3sch 10-11	Weekly sessions of behavioral modification (BM), improvement of fundamental motor skills (FMS) or a combination of both (BM/FMS)	I=9mt FU1=6mt FU2=12mt	BMI		Acc			BMI↓ for BM/FMS, PA↑ for BM and FMS	BMI↓ for BM/FMS, PA↑ for BM and FMS	88%
Switch[41] USA	RCT N=1323, Int=5sch, Con=5sch 8-11	Edu program to increase PA	I=6mt FU=6mt	BMI		Pedo			no effects on BMI, PA↑ in girls	BMI↓ in boys, PA↑ in girls	86%
Trois-Rivieres Study[29-32] Canada	CT N=546, Int/Con=1sch 6-11	PE 5h/wk vs 40min	I=6y FU=20y	BMI, SF, WC	submax Test	SR	BP, lipids		PA and Fitness↑	PA↑ in women, no effects for Fitness, Body fat, CVR	86%

RCT=randomized controlled trial; CT=controlled trial; CVR=cardiovascular risk; N=number of children participating in the study, Int=Intervention Group, Con=Control Group, PE=physical education; PA=physical activity, PES=physical education specialists, TT=trained teachers, I=Intervention, FU=Follow-up; Acc=accelerometers; Pedo=pedometers; SR=self-report questionnaire, Obs=Observation; TPA=total physical activity; MVPA=moderate-and-vigorous physical activity, VPA=vigorous physical activity; Sch=school, BMI=Body mass index (kg/m²), SF=skin fold, BP=blood pressure; WC=waist circumference; BM=behavioural modification; FMS=fundamental motor skills; BMC=bone mineral content

School's role in providing (sustained) physical activity

As children spend the majority of their waking hours in the school setting, school has an enormous potential to contribute to public health concerns. Previous review articles showed that school-based physical activity interventions successfully increased children's physical activity in school[44-47], whereas the transfer to out-of-school physical activity did not occur. Overall physical activity and fitness were often not assessed leaving the overall efficacy of such programs open for debate. Our systematic update of more recent school-based physical activity programs revealed a more consistent picture of the effectiveness of programs on out-of-school and overall physical activity. This improved evidence could be explained by the important progress of quality of the included studies, for instance by using objective means of physical activity assessment by accelerometers.

Thereby, this finding is contradictory to the widely held theory of an 'activitystat' existence. The activitystat theory suggests that there is a homeostatic regulation of total energy expenditure by an 'activitystat' that is built in[48, 49]. Based on this principle additional in-school physical activity would be compensated by being less active out-of-school[50-52] thereby maintaining overall energy expenditure. This is a highly important question if one believes in prevention of chronic diseases through physical activity. Only if a physical activity intervention is able to increase overall physical activity or at least health-enhancing physical activity, it has the potential to prevent disease. Our review clearly indicated that well-designed trials were successful not only at increasing in-school, but also out-of-school and overall physical activity. Thereby, the role of physical education is of particular interest. As shown in Chapter 5, even if children's physical activity levels during physical education have been relatively low, physical education contributed substantially to overall physical activity. Moreover, on days with physical education, children were considerably more active than on days without physical education. The fact that the additional activity on days with physical education was about the same amount of physical activity that children spent during the physical education lesson, supports the finding that physical activity was not compensated out-of-school and thereby argues against the activitystat theory. The hypothesis of an activitystat existence, and with it the question whether children's physical activity can be modulated by environmental changes is intensively discussed[53-55]. However, study results arguing for a physical activity compensation out-of-school were based on self-reported physical activity data[56] or a highly selective and small sample of children[50-52] and remain to be confirmed.

How to intervene for increasing children's health?

One of the research questions that was addressed in our review article (Chapter 3) was to highlight effective intervention strategies. The most successful school-based physical activity interventions had the design of a randomized controlled trial and were done in children rather than adolescents. The intervention program used a mandatory (rather than voluntary) and multi-component approach including physical education, behavioral modification or a combination, and was integrated into the school curriculum over one school year. Furthermore, they integrated physical education experts and tried to involve family members. Thereby, KISS fulfilled most of these strategies by being a randomized controlled trial in children with a mostly mandatory and multi-component physical activity program in and outside physical education over one school year and the inclusion of physical education experts. Thus, KISS had excellent pre-conditions for being an effective program. Indeed, the results after nine month of intervention have been promising. KISS improved cardiovascular health, physical activity levels as well as bone health of the children in concert. Thereby, every outcome has its own exercise characteristics to be successful. The disappearance of some of the long-term effects may be the price we had to pay since a general program was less tailored to a specific outcome as if there would have been only one outcome.

Evidence-based recommendations[57, 58] for cardiovascular risk factors suggest that effective intervention studies aiming at increasing aerobic fitness included three weekly sessions of at least 30 minutes of continuous vigorous intensity. Little evidence exists for interventions aiming at decreasing normotensive children's blood pressure. However, studies done in hypertensive youth showed that effective exercise parameters are similar to those for aerobic fitness (30 minutes, three times a week with vigorous physical activity). To improve lipid and lipoprotein levels, it has been suggested that interventions of at least four months are needed with exercise sessions of 40 minutes in at least moderate intensity, five times a week. The loss of effects on cardiovascular risk factors including waist circumference, lipids, glucose and blood pressure suggests that the program was not sufficiently maintained to keep effects on cardiovascular health. The newest guidelines have become much more 'demanding' with a recommendation of at least 90 minutes of moderate-and-vigorous physical activity as minimum for cardiovascular health maintenance[10, 59].

For bone health, recent review articles[60, 61] concluded that effective intervention programs should have a duration of at least seven months and include high impact exercises, performed in at least three loading sessions per week of 10 to 15 minutes each. Animal studies additionally showed that the effect of loading increased with the exercises divided into several shorter sessions per day[62, 63]. Since only few intervention studies have assessed training load by assessing size and extent of impact loading properly, it remains unclear how high loading has to be for stimulating bone response during growth. Some few studies measured the exact loading regimen. In a randomized controlled trial in boys, the investigators measured ground reaction forces of two-footed drop landings off a 60 cm high box. This corresponded to ground reaction forces of eight times body weight. The intervention program of 100 of these drop jumps, three times per week over seven months resulted in significantly enhanced bone mineral content at femur and lumbar spine[64]. This is in concert with another drop jump intervention reporting that forces having osteogenic potential need to be greater than 3.5 times body weight per leg[21].

Thus, is it possible to bring all this together in one general physical activity program? From a public health perspective the reach of different health outcomes with the same program is without any doubt much more attractive. A major aspect of such a program has probably to be encouraging children to enjoy and maintain an active lifestyle. However, as most of the beneficial effects have diminished after the program, one school year of a general intervention is probably not enough for a lasting behavioral change to occur.

RELEVANCE OF THE RESULTS

To fully comprehend the effects of an intervention study, it is important to sort out the clinical relevance of the results. This might be considered from two point of views including the population perspective on one hand and the individual perspective on the other.

On a population level, even small effects in an outcome are expected to have a considerable impact on public health[65]. This can be explained by a shift of the population curve (see Figure 10.2) in the favourable direction as i.e. documented for the cardiovascular risk score. More precisely, we have found for the cardiovascular risk score a statistically significant reduction of the intervention compared to the control group of 0.18 (95% confidence interval: −0.29 to −0.06) z-score units after the intervention of one school year. In their work, Andersen et al[10] defined individuals with a cardiovascular risk score above one standard deviation as being at high cardiovascular risk. Assuming a normal distributed cardiovascular risk with a median of zero on population level, the prevalence of a high cardiovascular risk would be by definition 16% (corresponding to the area under the normal distribution curve with $x > 1$ standard deviations). If KISS led to a shift of the median to the left by 0.18 z-score units, this would have led to a remarkable reduction of the (virtual) prevalence of a high cardiovascular risk from 16% to 12%, under the assumption that the effects were the same for all children. Obviously, this calculation can be done for all health outcomes studied in KISS indicating that even if obtained effects have been small after one school year, on a population level, they might still have a relevant impact.

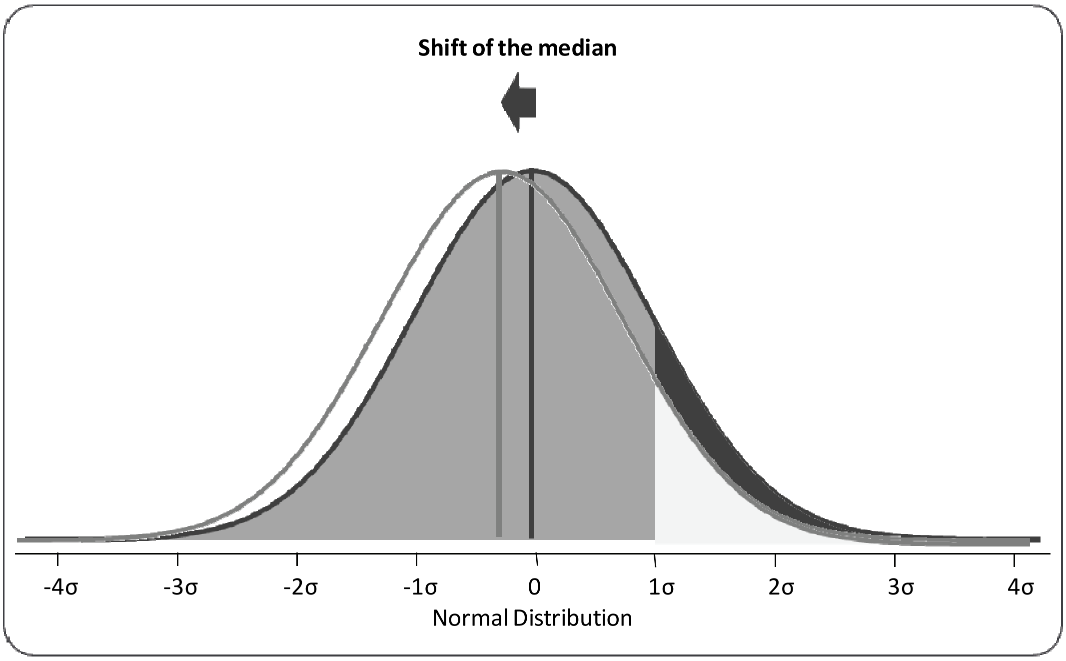

Figure 10.2 Theoretical model of the shift of the median on population level

The small effects on cardiovascular risk after one school year might even be important on the individual level. An autopsy study of persons dying incidentally in a road accident showed that already in childhood, the extent of atherosclerotic lesions in aorta and coronary arteries were positively correlated to cardiovascular risk factors(66). Thereby, the combination of multiple cardiovascular risk factors was of particular significance, since the extend of atherosclerotic lesions in the coronary arteries was eight to twelve times as high in people with three or more cardiovascular risk factors than in those with none. These findings led the authors to conclude that interventions aiming at reducing cardiovascular risk factors may retard the development of atherosclerosis if undertaken early in life.

Regarding bone health, it was predicted by a mathematical model that on population level, an increase of 10% in peak bone mass may delay the development of osteoporosis by 13 years(67). Thereby, a change of 10% corresponds to almost one standard deviation from population mean. Notably, the obtained benefits of KISS after nine month of intervention have been 4.7-8.4%. A meta-analysis in older women summarized that with each standard deviation decrease in bone mineral density, the age-adjusted risk for osteoporotic fractures increased by 50%(68). In this context, one could estimate that even small increases in peak bone mass could have a considerable impact on lifetime fracture risk – provided that effects gained during growth persisted into late adulthood.

Reflecting the relevance of the obtained effects, it is necessary to keep in mind that most of the measured parameters are known to track from childhood into adulthood. There are indications that, even if correlations are relatively weak, physical activity levels at a young age are related to an individual's adult physical activity level[69, 70]. Further, it has been shown that an unfit or overweight child is more likely to have low fitness or high body weight at adult age than its fit or normal weight counterpart[71, 72]. As also cardiovascular risk factors[73-75] and bone mass[76-78] tend to track into adulthood, promotion of a healthy lifestyle already in young years is of paramount importance.

METHODOLOGICAL CHALLANGES

To our knowledge, this is the first study of a school-based physical activity intervention that documents beneficial changes in all these parameters. Furthermore, KISS is one of the few intervention studies with a follow-up assessment three years after the intervention has stopped.

There are several strengths of the study which have to be mentioned:

(1) Being integrated into the school curriculum, the intervention program was mandatory for all children, even those who would probably escape if they had free choice.
(2) With 93%, participation rate for post-intervention measurements was high which minimizes selection bias.
(3) The program was designed in a matter that it was enjoyable for children and that it could be implemented on a large population, which means that once we have provided physical education experts and classroom teachers with the intervention tools, they conducted the program autonomously.
(4) Being a randomized controlled trial, KISS had a stringent design in accordance with CONSORT guidelines[79].
(5) Most measurements were done with objective and validated assessment tools.

However, there are a few features to be critically examined that may be taken as limitations:

Representativeness of the sample

An ideal scenario for each randomized controlled trial is to have a representative sample. In order to be representative for Switzerland, the original sample was randomly selected on the school level and included rural and urban areas with a migrant population of 10-30%. Even if school systems differ between countries, the Swiss population can be taken as representative of central Europe with the limitation that KISS included only the German part of Switzerland, excluding the French socio-cultural background that may have been important for the French and more Latin background. Therefore, the results of the study may to a certain degree also apply to many Western countries, but should be taken cautiously if Latin countries are compared. Participation rates for the different measurement outcomes during the post-intervention or the follow-up assessment varied markedly. This might have introduced some bias. To appraise this possible bias, we scrutinized characteristics of participating compared to non-participating children. Particularly the high drop-out rate at the 3-year follow-up is thereby of interest. Of the 502 children participating at baseline measurements, only 296 (59%) could have been recruited for follow-up measurements. Thereby, among the participants there have been more former first than fifth graders, slightly more girls than boys and fewer children with migrant or low socioeconomic background. Dropout of children from ethnical or socioeconomic minorities is a known public health problem[80-82] that is not yet solved properly. As children of low socioeconomic status and/or children of migrant background are especially at risk for being overweight and physically inactive[83, 84], this limitation has to be taken seriously and should be addressed by acknowledging a possibly reduced generalizability of the follow-up findings. However, it has to be kept in mind that particularly the school setting provides the opportunity to include these children without any stigmatization even if they did not participate in the measurement, they could not escape from the curriculum change during the intervention year. Thus, further investigations with higher sample sizes are needed to test long-term effects of school-based physical activity interventions including both, 'normal' children and children with migrant and/or low socioeconomic background.

Despite all this limitation due to drop-outs, bias should not have been too high, since among follow-up participants baseline values for children in the intervention and control group were comparable for all primary outcomes except body mass index. As skinfold thickness and waist circumference were not different, the meaning of a different body mass index is questionable. Despite these comparabilities, the KISS follow-up had included a selected population with more dropouts in the migrant, overweight and inactive population without doubt. Although this is a common finding in long-term epidemiological studies, we do not know the extent of bias this has created. However, since characteristics were comparable between groups, internal validity is given and still allows a meaningful interpretation of the study results. The loss of external validity on the other hand leads to a reduced generalizability[85].

Using standardized and continuous outcome values

Chronic disease is normally studied as dichotomized outcome; either there is disease or there is no disease. Since in children chronic diseases do usually not appear, intermediate health outcomes are used to identify pre-pathological processes of these diseases[86]. However, these intermediate health outcomes are not well defined in children. With the exception of body mass index and blood pressure, there are no established cut-off points for risk factors in children, neither for bone parameters nor for factors defining cardiovascular risk. In addition, it may even be more appropriate to define risk factors as continuous parameters with continuously increasing values documenting continuously increasing risk without setting a yet undefined cut-off that may categorize children into a wrong category and allows a deeper understanding of the dose-response relationships. Further, every dichotomization of continuous data reduces the predictive and statistical power of an observation[87]. Due to this, all our outcome variables were transformed into sex- and grade- or pubertal stage-related z-scores and treated as continuous data. A limitation of using internal z-scores is that the score is specific to the sample population from which the z-score derives and potentially lead to bias because of the reduced participation rate, especially for follow-up measures.

Measuring physical activity by accelerometry

Even if accelerometry is one of the best available techniques for physical activity assessment, it still has its limitations. As physical activity is characterized by a high intra-individual day-to-day variability[88, 89], several days of measurement are needed to provide reliable information on physical activity patterns. In children, 4-5 days of monitoring are necessary to achieve a reliability of 0.80[89]. Despite this, physical activity levels are influenced by several environmental factors (i.e. poor weather, winter season) particularly in children[90-92]. Thus, even with seven days of measurement, we do not know if the measured week was representative for the child's habitual physical activity. There are no studies done yet in which week to week variability has been tested. Further, the accelerometers used in this study were of one dimensional character. They measured body accelerations only in vertical direction. Thus, common childhood activities such as bicycling, skateboarding or swimming may not be detected accurately, which may lead to an underestimation of true physical activity levels. Further, the accelerometer summarizes the raw acceleration over a predefined time interval by integrating the single accelerations over a predefined time interval, the so called epoch time. Due to the limited memory capacity in 2005 when the study started and to be comparable to other studies, we decided to use an epoch time of 60 seconds. This is a critical issue, particularly because children's physical activity is characterized by short and intense activity bouts of only a few seconds[93, 94]. During the last few years, technical specifications of the accelerometer devices have significantly advanced. The newest accelerometer generation allows to measure raw acceleration at a frequency of up to 100 Hz over several days without integrating the signal over a certain epoch time. Thus, instead of the device-specific, arbitrary activity unit 'counts', newer devices express their signal in raw acceleration (in m/s^2). This leads to new possibilities, particularly for research on exercise related bone adaptation for which loading has to include very short loading bouts with high strain rates which are not accurately detectable by an epoch time of 60 seconds.

Measuring cardiovascular risk factors

As mentioned above, the principle of summarizing z-scores of multiple cardiovascular risk factors has been widely accepted in children. However, there is still no consensus on which individual factors should be included into the score[57, 95, 96]. Another critical issue is the weighting of the individual factors. Due to a complete lack in the literature, we assumed that each individual factor is equally weighted in predicting future cardiovascular disease in the current study. It may well be that a high fasting glucose as expression of an elevated insulin resistance, and elevated waist circumference is more detrimental than low high density lipoprotein-cholesterol levels as these factors showed the strongest associations with heart disease in adulthood[75, 97]. Children were asked to come in fasting state and we excluded data if children had reported that they ate breakfast prior to the blood withdrawal. However, we do not have absolute certainty that all blood samples were taken in fasting state which may have biased individual cardiovascular risk scores.

Aerobic fitness, as a determinant of cardiovascular health was measured by a 20-meter shuttle-run test. This test is a validated, commonly used field test to assess aerobic capacity[98]. However, as every maximal test, especially field tests, results might be influenced by motivation of the children which could have led to submaximal tests in unmotivated children. One method to ensure that children achieved their maximal performance is to measure heart rate during testing and assess maximal heart rate. This was done for the follow-up measurements. As most of the children achieved maximal heart rate values, we are confident that children reached their maximal performance during the previous testings alike. Nevertheless, we do not know whether this was also true for the children that dropped out earlier.

Measuring bone health by dual energy X-ray absorptiometry

DXA is widely used in the clinical setting for the diagnosis of osteoporosis. As most widely available technique it has succeed in entering paediatric research but some limitations have to be acknowledged. This radiological technique measures bone mineral content and bone mineral density. Bone mineral content is thereby derived from the amount of x-rays absorbed in the antero-posterior direction and expressed as grams. Bone mineral density is then calculated by dividing bone mineral content by the surface area of the bone that is visible on the antero-posterior plane expressed by grams per area (g/cm^2). As bone mineral density measured by DXA is therefore not a true volumetric density, but an areal density, it does not take into account the depth of bones and the three-dimensional growth[99]. This is of particular challenge in children and adolescence in whom bone size and shape are growing in concert but not at the same extent and speed. To minimize this problem, we used maturation and sex-adjusted bone values that were further adjusted for the children's height. Further, DXA is not able to measure bone structure or architecture which is an important determinant of bone strength[100]. Thus, even if DXA is considered as 'gold standard' for the assessment of bone mass, there is growing interest and use of peripheral quantitative computed tomography (pQCT) methods, since they assess volumetric bone mineral density in three dimensions and shed light on structural components of bone. However, compared to DXA, these methods are more expensive, have a higher radiation dose and there is still no consensus on the standardization of pQCT techniques to measure the growing skeleton reliably[101, 102].

PERSPECTIVES

Longer life expectancy is assumed to change the demographic landscape of the next decades. It is estimated that chronic diseases such as osteoporosis and cardiovascular diseases are becoming more prevalent, and with it, primary prevention more important. New research methods and every gained knowledge may therefore lead to new perspectives in the prevention of osteoporosis and cardiovascular diseases.

Perspectives on research level

New possibilities in better assessing bone structure that defines its strength and physical activity assessment that includes timing, extent and its dimension entail new perspectives in osteoporosis research. The most recent evolution in in-vivo bone strength measurement is high resolution pQCT (HR-pQCT) which allows to measure volumetric bone microarchitecture of the distal radius and tibia. The high resolution allows not only to assess bone mineral content in general, but to analyze mineralization characteristics of cortical and trabecular bone separately[103]. Further, computational post processing allows strength and failure analyses of measured bone by finite element analysis[104, 105]. The concept of finite element analysis is that biomechanical properties of a complex system can be determined through subdivision into small cubic elements with assumed biomechanical properties. Then, a compression test can be simulated and based on the results, stiffness and strength of the whole structure will be calculated[105-108]. Even if there is still no clear consensus on how to reliably apply HR-pQCT in the growing skeleton of children, HR-pQCT measurements are increasingly used[109-111] and will surely answer important questions in osteoporosis research.

Together with the newest accelerometer generation which allows assessing body acceleration in high frequency raw acceleration values leaving the undefined arbitrary unit of counts that have been taken as surrogate measure of accelerations behind, it is going to be possible to measure extent and pattern of specific bone loading during daily life. Until now, the extent of loading could only be assessed by the use of force plates that assessed ground reaction forces. These measurements had to be done in laboratory conditions and did not offer a picture of what is going on in daily life. With more accurate measurement techniques of accelerometers, it will be possible to gain knowledge about the dose-response relationships of physical activity and bone growth. This will allow ameliorating the definition of tailored exercise interventions and physical activity guidelines for an optimal bone development during growth or boning maintenance at adult life. So far, existing physical activity guidelines are all based on validations of accelerometer derived activity data with metabolic equivalents[112-116] which are not necessarily representative for skeletal health.

The rapid advances in technology and data processing techniques provide other new opportunities in physical activity research. Yet, accelerometers offer information about the pattern of physical activity behavior (*when* and *how* intensive physical activity occurs), however, objective contextual information (*where* and *why* physical activity occurs) is limited. First advances addressing this issue have been made by coupling accelerometer data with Global Positioning System (GPS) technology[117-120]. GPS is a satellite-based system providing information about a person's location at any point in time and together with Geographic Information System (GIS) describing the characteristics of the surroundings, it provides rich information on the context of a person's behavior. Even if first studies have been published[118, 119, 121], combined devices still have technical and logistical constraints and further work is needed[120, 122]. However, knowing more about the location and context of children's physical activity may arouse new public health strategies.

Perspectives on epidemiological level

On the level of cardiovascular health, a crucial point from a public health perspective is the identification and treatment of high risk children. Since clinical symptoms of chronic disease do usually not appear in childhood, we have to consider intermediate health outcomes. However, in the clinical practice it might be more feasible to identify high risk children by easy assessable behavior parameters. While it is known that individual behavior parameters, such as physical activity, time spent outdoor, media consumption etc. are associated with a higher cardiovascular risk[10, 123, 124], it remains unclear how these factors interact with each other. It is highly probable that they are related to each other and children with more negative health behaviors might be at a higher risk for developing cardiovascular disease. By addressing this question, our data showed that children with three and more of these negative health behavior parameters at baseline in comparison to those with no or at most one negative health behavior, had a 2.6 times higher risk of having an increased cardiovascular risk score four years later[125]. Thus, children with a clustering of negative health behaviors are at high risk for developing chronic disease later in life and should be indentified and treated as early as possible.

During the last years, it has become more and more evident that school-based intervention programs have the potential to improve children's physical health. However, it still remains unclear whether gained benefits are maintained into later adolescence or adulthood. Our study as well as some scarce data from the literature (see Table 10.1) offers first indications that this is at least partly the case. However due to the immense drop-out rate in all of these studies including ours, we have to be careful in generalizing the results. Further intervention studies with longer follow-up periods and with larger sample sizes are needed to address this issue more thoroughly. Moreover, effective implementation strategies are needed and have to be tested.

IMPLEMENTATION

The results of KISS indicated that a physical activity program in school can have promising effects on children's physical health. However, as most of the effects have not been maintained after cessation of the program, one could conclude that the duration of only one school year of intervention is not sufficient or, as long-term effects are lacking, that the money is not worth it. This statement may be premature as many intervention studies have not assessed long-term effects. In addition, as Durlak and DuPre[126] stated, "developing effective intervention programs is only the first step toward improving health and well-being of populations". The key process is to "transfer these effective programs into the real world setting". This leads to the question if an intervention like KISS can be implemented area-wide into the normal school curriculum.

Is KISS the panacea for children's health? KISS was a 1.5-million Swiss Francs project, of which a substantial amount was used for the conduction of the intervention. The systematic update of existing intervention studies clearly revealed that the multi-component approach seems to be the most promising strategy for the success of a school-based physical activity intervention study. KISS had a multi-component character by intervening with curricular, educational and environmental elements. The inclusion of a variety of strategies to enhance physical activity may have reached more children and it is unclear whether a reduction of the spectrum of activities would obtain the same beneficial effects. Since the costs for a wide implementation of KISS are probably too high, it has to be analyzed how KISS could be adapted for the real life situation. Whilst not committing ourselves on 'the one' most effective component of the intervention – although this was not analyzed in detail – we think that THE important step may be the increase in physical education's quality and quantity. It has been shown in other countries that the inclusion of physical education experts already in primary school was an effective way to increase children's physical activity levels[33, 127]. This might even be a cost-effective solution. Despite the current political discussions about a reduction of the amount of physical education in the school curriculum, a second step of implementation should be physical education on a daily basis. We could show that children have been significantly more active on days with physical education at school (Chapter 5), whereas on days without physical education; only 43% of the children achieved the recommended amount of physical activity. If one considers that our intervention added an additional 16 minutes of moderate-and-vigorous physical activity on each school day, 60% of all children would have been sufficiently active by the actual physical activity recommendations. A first step into the direction of daily physical education time in Switzerland has been made by the implementation of J+S Kids, a program that educates and financially supports classroom teachers and sport coaches in the realization of additional school-related physical education lessons. However, since participation in these lessons is not mandatory for all children, it is likely that the program reaches mainly children who are already active and not those who would benefit most from participating. Monitoring and evaluating such an (adapted) program is a crucial point to get evidence whether this politically adapted “soft” solution is sufficient to at least maintain health of the children.

OVERALL CONCLUSION

In the light of the important role of children’s physical activity in prevention of chronic diseases later in life and the high amount of children not achieving current physical activity recommendations, the aim of this dissertation was to evaluate the effect of a school-based physical activity intervention on children’s cardiovascular and bone health. We conducted a stringent, multi-component physical activity program over nine months including daily physical education (i.e. two additional lessons per week, on top of three regular lessons), short physical activity breaks during academic lessons, and daily physical activity homework. The program succeeded at enhancing children’s physical activity and aerobic fitness, improved cardiovascular health and bone mass in children of the intervention compared to controls. However, while some of the beneficial effects disappeared three years after cessation of the program, sustained effects could be observed for aerobic fitness and impact loaded bone parameters, indicating that one year intervention was partially effective in maintaining exercise-related health effects. In consequence of the beneficial effects of KISS, an important next step is to develop effective implementation strategies. Improving physical education’s quality and quantity by a better education of classroom teachers or the inclusion of physical education experts in schools might be a promising first approach to improve children’s health and imprint an active lifestyle that is maintained throughout life. With this study, we contributed novel and important scientific findings that might also be important for political discussions regarding the importance of school-based physical activity and health promotion in children.

REFERENCES

(1) Blair SN, Goodyear NN, Gibbons LW, Cooper KH. Physical Fitness and Incidence of Hypertension in Healthy Normotensive Men and Women. JAMA. 1984; 252(4): 487.

(2) Lee CD, Blair SN, Jackson AS. Cardiorespiratory Fitness, Body Composition, and All-Cause and Cardiovascular Disease Mortality in Men. Am J Clin Nutr. 1999; 69(3): 373.

(3) Sandvik L, Erikssen J, Thaulow E, Erikssen G, Mundal R, Rodahl K. Physical Fitness as a Predictor of Mortality among Healthy, Middle-Aged Norwegian Men. N Engl J Med. 1993; 328(8): 533.

(4) Fogelholm M. Physical Activity, Fitness and Fatness: Relations to Mortality, Morbidity and Disease Risk Factors. A Systematic Review. Obes Rev. 2010; 11(3): 202.

(5) Twisk JW, Kemper HC, van Mechelen W. Prediction of Cardiovascular Disease Risk Factors Later in Life by Physical Activity and Physical Fitness in Youth: General Comments and Conclusions. Int J Sports Med. 2002; 23 Suppl 1: S44.

(6) Twisk JW, Kemper HC, van Mechelen W. The Relationship between Physical Fitness and Physical Activity During Adolescence and Cardiovascular Disease Risk Factors at Adult Age. The Amsterdam Growth and Health Longitudinal Study. Int J Sports Med. 2002; 23 Suppl 1: S8.

(7) Twisk JW, Kemper HC, van Mechelen W. Prediction of Cardiovascular Disease Risk Factors Later in Life by Physical Activity and Physical Fitness in Youth: Introduction. Int J Sports Med. 2002; 23 Suppl 1: S5.

(8) Paffenbarger RS, Jr., Hyde RT, Wing AL, Hsieh CC. Physical Activity, All-Cause Mortality, and Longevity of College Alumni. N Engl J Med. 1986; 314(10): 605.

(9) Paffenbarger RS, Jr., Hyde RT. Exercise in the Prevention of Coronary Heart Disease. Prev Med. 1984; 13(1): 3.

(10) Andersen LB, Harro M, Sardinha LB, Froberg K, Ekelund U, Brage S, et al. Physical Activity and Clustered Cardiovascular Risk in Children: A Cross-Sectional Study (the European Youth Heart Study). Lancet. 2006; 368(9532): 299.

(11) Mujika I, Padilla S. Cardiorespiratory and Metabolic Characteristics of Detraining in Humans. Med Sci Sports Exerc. 2001; 33(3): 413.

(12) Mujika I, Padilla S. Detraining: Loss of Training-Induced Physiological and Performance Adaptations. Part Ii: Long Term Insufficient Training Stimulus. Sports Med. 2000; 30(3): 145.

(13) LeMura LM, von Duvillard SP, Andreacci J, Klebez JM, Chelland SA, Russo J. Lipid and Lipoprotein Profiles, Cardiovascular Fitness, Body Composition, and Diet During and after Resistance, Aerobic and Combination Training in Young Women. Eur J Appl Physiol. 2000; 82(5-6): 451.

(14) Robling AG, Hinant FM, Burr DB, Turner CH. Improved Bone Structure and Strength after Long-Term Mechanical Loading Is Greatest If Loading Is Separated into Short Bouts. J Bone Miner Res. 2002; 17(8): 1545.

(15) Warden SJ, Hurst JA, Sanders MS, Turner CH, Burr DB, Li J. Bone Adaptation to a Mechanical Loading Program Significantly Increases Skeletal Fatigue Resistance. J Bone Miner Res. 2005; 20(5): 809.

(16) Bass SL, Saxon L, Daly RM, Turner CH, Robling AG, Seeman E, et al. The Effect of Mechanical Loading on the Size and Shape of Bone in Pre-, Peri-, and Postpubertal Girls: A Study in Tennis Players. J Bone Miner Res. 2002; 17(12): 2274.

(17) Warden SJ. Breaking the Rules for Bone Adaptation to Mechanical Loading. J Appl Physiol. 2006; 100(5): 1441.

(18) Warden SJ, Fuchs RK, Castillo AB, Nelson IR, Turner CH. Exercise When Young Provides Lifelong Benefits to Bone Structure and Strength. J Bone Miner Res. 2007; 22(2): 251.

(19) Karlsson MK. Does Exercise During Growth Prevent Fractures in Later Life? Med Sport Sci. 2007; 51: 121.

(20) Gunter K, Baxter-Jones AD, Mirwald RL, Almstedt H, Fuchs RK, Durski S, et al. Impact Exercise Increases Bmc During Growth: An 8-Year Longitudinal Study. J Bone Miner Res. 2008; 23(7): 986.

(21) Gunter K, Baxter-Jones AD, Mirwald RL, Almstedt H, Fuller A, Durski S, et al. Jump Starting Skeletal Health: A 4-Year Longitudinal Study Assessing the Effects of Jumping on Skeletal Development in Pre and Circum Pubertal Children. Bone. 2008; 42(4): 710.

(22) Manios Y, Kafatos A. Health and Nutrition Education in Primary Schools in Crete: 10 Years Follow-up of Serum Lipids, Physical Activity and Macronutrient Intake. Br J Nutr. 2006; 95(3): 568.

(23) Manios Y, Kafatos A, Mamalakis G. The Effects of a Health Education Intervention Initiated at First Grade over a 3 Year Period: Physical Activity and Fitness Indices. Health Educ Res. 1998; 13(4): 593.

(24) Manios Y, Kafatos I, Kafatos A. Ten-Year Follow-up of the Cretan Health and Nutrition Education Program on Children's Physical Activity Levels. Prev Med. 2006; 43(6): 442.

(25) Kafatos A, Manios Y, Moschandreas J. Health and Nutrition Education in Primary Schools of Crete: Follow-up Changes in Body Mass Index and Overweight Status. Eur J Clin Nutr. 2005; 59(9): 1090.

(26) Klepp KI, Tell GS, Vellar OD. Ten-Year Follow-up of the Oslo Youth Study Smoking Prevention Program. Prev Med. 1993; 22(4): 453.

(27) Tell GS, Vellar OD. Physical Fitness, Physical Activity, and Cardiovascular Disease Risk Factors in Adolescents: The Oslo Youth Study. Prev Med. 1988; 17(1): 12.

(28) Tell GS, Vellar OD. Noncommunicable Disease Risk Factor Intervention in Norwegian Adolescents: The Oslo Youth Study. In: Hetzel B, Berenson,G., editor. Cardiovascular Risk Factors in Childhood: Epidemiology and Prevention. Amsterdam: Elsevier Science Publishers; 1987.
(29) Trudeau F, Laurencelle L, Tremblay J, Rajic M, Shephard RJ. A Long-Term Follow-up of Participants in the Trois-Riviäres Semi-Longitudinal Study of Growth and Development. Pediatr Exerc Sci. 1998; 10 366.
(30) Trudeau F, Laurencelle L, Tremblay J, Rajic M, Shephard RJ. Daily Primary School Physical Education: Effects on Physical Activity During Adult Life. Med Sci Sports Exerc. 1999; 31(1): 111.
(31) Shephard RJ, Lavallée, H. Impact of Enhanced Physical Education on Muscle Sttrength in the Prepubescent Child: Trois Rivières Revisited. Pediatr Exerc Sci. 1994; 6: 75.
(32) Shephard RJ. Long-Term Studies of Physical Activity in Children: The Trois-Rivières Experience. In: Binkhorst RA, Kemper, H.C.G., Saris W.H.M., editor. Children and Exercise Xi. Champaign, IL: Human Kinetics; 1985.
(33) McKenzie TL, Sallis JF, Kolody B, Faucette FN. Long-Term Effects of a Physical Education Curriculum and Staff Development Program: Spark. Res Q Exerc Sport. 1997; 68(4): 280.
(34) Sallis JF, McKenzie TL, Alcaraz JE, Kolody B, Faucette N, Hovell MF. The Effects of a 2-Year Physical Education Program (Spark) on Physical Activity and Fitness in Elementary School Students. Sports, Play and Active Recreation for Kids. Am J Public Health. 1997; 87(8): 1328.
(35) Sallis JF, McKenzie TL, Alcaraz JE, Kolody B, Hovell MF, Nader PR. Project Spark. Effects of Physical Education on Adiposity in Children. Ann N Y Acad Sci. 1993; 699: 127.
(36) Kelder SH, Mitchell PD, McKenzie TL, Derby C, Strikmiller PK, Luepker RV, et al. Long-Term Implementation of the Catch Physical Education Program. Health Educ Behav. 2003; 30(4): 463.
(37) McKenzie TL, Nader PR, Strikmiller PK, Yang M, Stone EJ, Perry CL, et al. School Physical Education: Effect of the Child and Adolescent Trial for Cardiovascular Health. Prev Med. 1996; 25(4): 423.
(38) Nader PR, Stone EJ, Lytle LA, Perry CL, Osganian SK, Kelder S, et al. Three-Year Maintenance of Improved Diet and Physical Activity: The Catch Cohort. Child and Adolescent Trial for Cardiovascular Health. Arch Pediatr Adolesc Med. 1999; 153(7): 695.
(39) Luepker RV, Perry CL, McKinlay SM, Nader PR, Parcel GS, Stone EJ, et al. Outcomes of a Field Trial to Improve Children's Dietary Patterns and Physical Activity. The Child and Adolescent Trial for Cardiovascular Health. Catch Collaborative Group. JAMA. 1996; 275(10): 768.
(40) McKenzie TL, Li D, Derby CA, Webber LS, Luepker RV, Cribb P. Maintenance of Effects of the Catch Physical Education Program: Results from the Catch-on Study. Health Educ Behav. 2003; 30(4): 447.
(41) Gentile DA, Welk G, Eisenmann JC, Reimer RA, Walsh DA, Russell DW, et al. Evaluation of a Multiple Ecological Level Child Obesity Prevention Program: Switch What You Do, View, and Chew. BMC Med. 2009; 7: 49.
(42) Salmon J, Ball K, Hume C, Booth M, Crawford D. Outcomes of a Group-Randomized Trial to Prevent Excess Weight Gain, Reduce Screen Behaviours and Promote Physical Activity in 10-Year-Old Children: Switch-Play. Int J Obes. 2008; 32(4): 601.
(43) Fuchs RK, Snow CM. Gains in Hip Bone Mass from High-Impact Training Are Maintained: A Randomized Controlled Trial in Children. J Pediatr. 2002; 141(3): 357.
(44) van Sluijs EMF, McMinn AM, Griffin S. Effectiveness of Interventions to Promote Physical Activity in Children and Adolescents: Systematic Review of Controlled Trials. Br Med J. 2007; 335(7622): 703.
(45) Dobbins M, De Corby K, Robeson P, Husson H, Tirilis D. School-Based Physical Activity Programs for Promoting Physical Activity and Fitness in Children and Adolescents Aged 6-18. Cochrane Database Syst Rev. 2009; (1): Cd007651.
(46) Salmon J, Booth ML, Phongsavan P, Murphy N, Timperio A. Promoting Physical Activity Participation among Children and Adolescents. Epidemiol Rev. 2007; 29: 144.
(47) De Meester F, van Lenthe FJ, Spittaels H, Lien N, De Bourdeaudhuij I. Interventions for Promoting Physical Activity among European Teenagers: A Systematic Review. Int J Behav Nutr Phys Act. 2009; 6.
(48) Rowland TW. The Biological Basis of Physical Activity. Med Sci Sports Exerc. 1998; 30(3): 392.
(49) Eisenmann JC, Wickel EE. The Biological Basis of Physical Activity in Children: Revisited. Pediatr Exerc Sci. 2009; 21(3): 257.
(50) Fremeaux AE, Mallam KM, Metcalf BS, Hosking J, Voss LD, Wilkin TJ. The Impact of School-Time Activity on Total Physical Activity: The Activitystat Hypothesis (Earlybird 46). Int J Obes. 2011; 35(10): 1277.
(51) Wilkin TJ, Mallam KM, Metcalf BS, Jeffery AN, Voss LD. Variation in Physical Activity Lies with the Child, Not His Environment: Evidence for an 'Activitystat' in Young Children (Earlybird 16). Int J Obes. 2006; 30(7): 1050.
(52) Mallam KM, Metcalf BS, Kirkby J, Voss LD, Wilkin TJ. Contribution of Timetabled Physical Education to Total Physical Activity in Primary School Children: Cross Sectional Study. Br Med J. 2003; 327(7415): 592.
(53) Reilly JJ. Can We Modulate Physical Activity in Children? Int J Obes. 2011; 35(10): 1266.
(54) Goodman A, Mackett RL, Paskins J. Testing the Activitystat Hypothesis: Authors' Response. Prev Med. 2012; 54(2): 178.
(55) Wilkin TJ. Can We Modulate Physical Activity in Children? No. Int J Obes. 2011; 35(10): 1270.

(56) Donnelly JE, Jacobsen DJ, Whatley JE, Hill JO, Swift LL, Cherrington A, et al. Nutrition and Physical Activity Program to Attenuate Obesity and Promote Physical and Metabolic Fitness in Elementary School Children. Obes Res. 1996; 4(3): 229.
(57) Andersen LB, Riddoch C, Kriemler S, Hills A. Physical Activity and Cardiovascular Risk Factors in Children. Br J Sports Med. 2011; 45(11): 871.
(58) Strong WB, Malina RM, Blimkie CJ, Daniels SR, Dishman RK, Gutin B, et al. Evidence Based Physical Activity for School-Age Youth. J Pediatr. 2005; 146(6): 732.
(59) World Health Organization. Global Recommendations on Physical Activity for Health. Geneva: WHO; 2010.
(60) Gunter KB, Almstedt HC, Janz KF. Physical Activity in Childhood May Be the Key to Optimizing Lifespan Skeletal Health. Exerc Sport Sci Rev. 2011.
(61) Hughes JM, Novotny SA, Wetzsteon RJ, Petit MA. Lessons Learned from School-Based Skeletal Loading Intervention Trials: Putting Research into Practice. Med Sport Sci. 2007; 51: 137.
(62) Robling AG, Burr DB, Turner CH. Recovery Periods Restore Mechanosensitivity to Dynamically Loaded Bone. J Exp Biol. 2001; 204(Pt 19): 3389.
(63) Robling AG, Hinant FM, Burr DB, Turner CH. Shorter, More Frequent Mechanical Loading Sessions Enhance Bone Mass. Med Sci Sports Exerc. 2002; 34(2): 196.
(64) Fuchs RK, Bauer JJ, Snow CM. Jumping Improves Hip and Lumbar Spine Bone Mass in Prepubescent Children: A Randomized Controlled Trial. J Bone Miner Res. 2001; 16(1): 148.
(65) Rose G. Rose's Strategy of Preventive Medicine. 2nd ed: Oxford University Press; 2008.
(66) Berenson GS, Srinivasan SR, Bao W, Newman WP, 3rd, Tracy RE, Wattigney WA. Association between Multiple Cardiovascular Risk Factors and Atherosclerosis in Children and Young Adults. The Bogalusa Heart Study. N Engl J Med. 1998; 338(23): 1650.
(67) Hernandez CJ, Beaupre GS, Carter DR. A Theoretical Analysis of the Relative Influences of Peak Bmd, Age-Related Bone Loss and Menopause on the Development of Osteoporosis. Osteoporos Int. 2003; 14(10): 843.
(68) Marshall D, Johnell O, Wedel H. Meta-Analysis of How Well Measures of Bone Mineral Density Predict Occurrence of Osteoporotic Fractures. Br Med J. 1996; 312(7041): 1254.
(69) Malina RM. Tracking of Physical Activity and Physical Fitness across the Lifespan. Res Q Exerc Sport. 1996; 67(3 Suppl): S48.
(70) Telama R. Tracking of Physical Activity from Childhood to Adulthood: A Review. Obes Facts. 2009; 2(3): 187.
(71) Twisk JW, Kemper HC, van Mechelen W. Tracking of Activity and Fitness and the Relationship with Cardiovascular Disease Risk Factors. Med Sci Sports Exerc. 2000; 32(8): 1455.
(72) Singh AS, Mulder C, Twisk JW, van Mechelen W, Chinapaw MJ. Tracking of Childhood Overweight into Adulthood: A Systematic Review of the Literature. Obes Rev. 2008; 9(5): 474.
(73) Nicklas TA, von Duvillard SP, Berenson GS. Tracking of Serum Lipids and Lipoproteins from Childhood to Dyslipidemia in Adults: The Bogalusa Heart Study. Int J Sports Med. 2002; 23 Suppl 1: S39.
(74) Berenson GS. Childhood Risk Factors Predict Adult Risk Associated with Subclinical Cardiovascular Disease. The Bogalusa Heart Study. Am J Cardiol. 2002; 90(10C): 3L.
(75) Srinivasan SR, Myers L, Berenson GS. Predictability of Childhood Adiposity and Insulin for Developing Insulin Resistance Syndrome (Syndrome X) in Young Adulthood: The Bogalusa Heart Study. Diabetes. 2002; 51(1): 204.
(76) Melton LJ, 3rd, Atkinson EJ, Khosla S, Oberg AL, Riggs BL. Evaluation of a Prediction Model for Long-Term Fracture Risk. J Bone Miner Res. 2005; 20(4): 551.
(77) Foley S, Quinn S, Jones G. Tracking of Bone Mass from Childhood to Adolescence and Factors That Predict Deviation from Tracking. Bone. 2009; 44(5): 752.
(78) Budek AZ, Mark T, Michaelsen KF, Molgaard C. Tracking of Size-Adjusted Bone Mineral Content and Bone Area in Boys and Girls from 10 to 17 Years of Age. Osteoporos Int. 2010; 21(1): 179.
(79) Campbell MK, Elbourne DR, Altman DG. Consort Statement: Extension to Cluster Randomised Trials. Br Med J. 2004; 328(7441): 702.
(80) Reijneveld SA. Ethnic Differences in Health and Use of Health Care: The Questions to Be Answered. Int J Public Health. 2010; 55(5): 353.
(81) Caprio S, Daniels SR, Drewnowski A, Kaufman FR, Palinkas LA, Rosenbloom AL, et al. Influence of Race, Ethnicity, and Culture on Childhood Obesity: Implications for Prevention and Treatment. Obesity. 2008; 16(12): 2566.
(82) Muckelbauer R, Libuda L, Clausen K, Toschke AM, Reinehr T, Kersting M. Immigrational Background Affects the Effectiveness of a School-Based Overweight Prevention Program Promoting Water Consumption. Obesity. 2010; 18(3): 528.
(83) Lasserre AM, Chiolero A, Cachat F, Paccaud F, Bovet P. Overweight in Swiss Children and Associations with Children's and Parents' Characteristics. Obesity. 2007; 15(12): 2912.
(84) Freitas D, Maia J, Beunen G, Claessens A, Thomis M, Marques A, et al. Socio-Economic Status, Growth, Physical Activity and Fitness: The Madeira Growth Study. Ann Hum Biol. 2007; 34(1): 107.
(85) Barry AE. How Attrition Impacts the Internal and External Validity of Longitudinal Research. J Sch Health. 2005; 75(7): 267.
(86) Steinberger J, Daniels SR, Eckel RH, Hayman L, Lustig RH, McCrindle B, et al. Progress and Challenges in Metabolic Syndrome in Children and Adolescents: A Scientific Statement from the American Heart Association Atherosclerosis,

Hypertension, and Obesity in the Young Committee of the Council on Cardiovascular Disease in the Young; Council on Cardiovascular Nursing; and Council on Nutrition, Physical Activity, and Metabolism. Circulation. 2009; 119(4): 628.

(87) Ragland DR. Dichotomizing Continuous Outcome Variables: Dependence of the Magnitude of Association and Statistical Power on the Cutpoint. Epidemiology. 1992; 3(5): 434.

(88) Fairclough SJ, Butcher ZH, Stratton G. Whole-Day and Segmented-Day Physical Activity Variability of Northwest England School Children. Prev Med. 2007; 44(5): 421.

(89) Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using Objective Physical Activity Measures with Youth: How Many Days of Monitoring Are Needed? Med Sci Sports Exerc. 2000; 32(2): 426.

(90) Carson V, Spence JC. Seasonal Variation in Physical Activity among Children and Adolescents: A Review. Pediatr Exerc Sci. 2010; 22(1): 81.

(91) Belanger M, Gray-Donald K, O'Loughlin J, Paradis G, Hanley J. Influence of Weather Conditions and Season on Physical Activity in Adolescents. Ann Epidemiol. 2009; 19(3): 180.

(92) Uijtdewilligen L, Nauta J, Singh AS, van Mechelen W, Twisk JW, van der Horst K, et al. Determinants of Physical Activity and Sedentary Behaviour in Young People: A Review and Quality Synthesis of Prospective Studies. Br J Sports Med. 2011; 45(11): 896.

(93) Bailey RC, Olson J, Pepper SL, Porszasz J, Barstow TJ, Cooper DM. The Level and Tempo of Children's Physical Activities: An Observational Study. Med Sci Sports Exerc. 1995; 27(7): 1033.

(94) Baquet G, Stratton G, Van Praagh E, Berthoin S. Improving Physical Activity Assessment in Prepubertal Children with High-Frequency Accelerometry Monitoring: A Methodological Issue. Prev Med. 2007; 44(2): 143.

(95) Steele RM, Brage S, Corder K, Wareham NJ, Ekelund U. Physical Activity, Cardiorespiratory Fitness, and the Metabolic Syndrome in Youth. J Appl Physiol. 2008; 105(1): 342.

(96) Chi CH, Wang Y, Wilson DM, Robinson TN. Definition of Metabolic Syndrome in Preadolescent Girls. J Pediatr. 2006; 148(6): 788.

(97) Chen W, Srinivasan SR, Li S, Xu J, Berenson GS. Metabolic Syndrome Variables at Low Levels in Childhood Are Beneficially Associated with Adulthood Cardiovascular Risk: The Bogalusa Heart Study. Diabetes Care. 2005; 28(1): 126.

(98) Leger LA, Mercier D, Gadoury C, Lambert J. The Multistage 20 Metre Shuttle Run Test for Aerobic Fitness. J Sports Sci. 1988; 6(2): 93.

(99) van Rijn RR, Van Kuijk C. Of Small Bones and Big Mistakes; Bone Densitometry in Children Revisited. Eur J Radiol. 2009; 71(3): 432.

(100) Kontulainen SA, Hughes JM, Macdonald HM, Johnston JD. The Biomechanical Basis of Bone Strength Development During Growth. Med Sport Sci. 2007; 51: 13.

(101) Zemel B, Bass S, Binkley T, Ducher G, Macdonald H, McKay H, et al. Peripheral Quantitative Computed Tomography in Children and Adolescents: The 2007 Iscd Pediatric Official Positions. J Clin Densitom. 2008; 11(1): 59.

(102) Zemel BS. Quantitative Computed Tomography and Computed Tomography in Children. Curr Osteoporos Rep. 2011; 9(4): 284.

(103) Boutroy S, Bouxsein ML, Munoz F, Delmas PD. In Vivo Assessment of Trabecular Bone Microarchitecture by High-Resolution Peripheral Quantitative Computed Tomography. J Clin Endocrinol Metab. 2005; 90(12): 6508.

(104) Mueller TL, Christen D, Sandercott S, Boyd SK, van Rietbergen B, Eckstein F, et al. Computational Finite Element Bone Mechanics Accurately Predicts Mechanical Competence in the Human Radius of an Elderly Population. Bone. 2011; 48(6): 1232.

(105) Pistoia W, van Rietbergen B, Lochmuller EM, Lill CA, Eckstein F, Ruegsegger P. Image-Based Micro-Finite-Element Modeling for Improved Distal Radius Strength Diagnosis: Moving from Bench to Bedside. J Clin Densitom. 2004; 7(2): 153.

(106) Pistoia W, Van Rietbergen B, Lochmuller EM, Lill CA, Eckstein F, Ruegsegger P. Estimation of Distal Radius Failure Load with Micro-Finite Element Analysis Models Based on Three-Dimensional Peripheral Quantitative Computed Tomography Images. Bone. 2002; 30(6): 842.

(107) van Lenthe GH, Muller R. Prediction of Failure Load Using Micro-Finite Element Analysis Models: Toward in Vivo Strength Assessment. Drug Discovery Today: Technologies. 2006; 3(2): 221.

(108) Krug R, Burghardt AJ, Majumdar S, Link TM. High-Resolution Imaging Techniques for the Assessment of Osteoporosis. Radiol Clin North Am. 2010; 48(3): 601.

(109) Nishiyama KK, Macdonald HM, Moore SA, Fung T, Boyd SK, McKay HA. Cortical Porosity Is Higher in Boys Compared with Girls at the Distal Radius and Distal Tibia During Pubertal Growth: An Hr-Pqct Study. J Bone Miner Res. 2011; [Epub ahead of print].

(110) de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a Who Growth Reference for School-Aged Children and Adolescents. Bull World Health Organ. 2007; 85(9): 660.

(111) Kirmani S, Christen D, van Lenthe GH, Fischer PR, Bouxsein ML, McCready LK, et al. Bone Structure at the Distal Radius During Adolescent Growth. J Bone Miner Res. 2009; 24(6): 1033.

(112) Kim Y, Beets MW, Welk GJ. Everything You Wanted to Know About Selecting the "Right" Actigraph Accelerometer Cut-Points for Youth, But...: A Systematic Review. J Sci Med Sport. 2012; [Epub ahead of print].

(113) Freedson P, Pober D, Janz KF. Calibration of Accelerometer Output for Children. Med Sci Sports Exerc. 2005; 37(11 Suppl): S523.

(114) Puyau MR, Adolph AL, Vohra FA, Butte NF. Validation and Calibration of Physical Activity Monitors in Children. Obes Res. 2002; 10(3): 150.
(115) Trost SG, Ward DS, Moorehead SM, Watson PD, Riner W, Burke JR. Validity of the Computer Science and Applications (Csa) Activity Monitor in Children. Med Sci Sports Exerc. 1998; 30(4): 629.
(116) Treuth MS, Schmitz K, Catellier DJ, McMurray RG, Murray DM, Almeida MJ, et al. Defining Accelerometer Thresholds for Activity Intensities in Adolescent Girls. Med Sci Sports Exerc. 2004; 36(7): 1259.
(117) Krenn PJ, Titze S, Oja P, Jones A, Ogilvie D. Use of Global Positioning Systems to Study Physical Activity and the Environment: A Systematic Review. Am J Prev Med. 2011; 41(5): 508.
(118) Rodriguez DA, Brown AL, Troped PJ. Portable Global Positioning Units to Complement Accelerometry-Based Physical Activity Monitors. Med Sci Sports Exerc. 2005; 37(11 Suppl): S572.
(119) Troped PJ, Oliveira MS, Matthews CE, Cromley EK, Melly SJ, Craig BA. Prediction of Activity Mode with Global Positioning System and Accelerometer Data. Med Sci Sports Exerc. 2008; 40(5): 972.
(120) Duncan MJ, Badland HM, Mummery WK. Applying Gps to Enhance Understanding of Transport-Related Physical Activity. J Sci Med Sport. 2009; 12(5): 549.
(121) Wheeler BW, Cooper AR, Page AS, Jago R. Greenspace and Children's Physical Activity: A Gps/Gis Analysis of the Peach Project. Prev Med. 2010; 51(2): 148.
(122) Butte NF, Ekelund U, Westerterp KR. Assessing Physical Activity Using Wearable Monitors: Measures of Physical Activity. Med Sci Sports Exerc. 2012; 44(1 Suppl 1): S5.
(123) Cleland V, Crawford D, Baur LA, Hume C, Timperio A, Salmon J. A Prospective Examination of Children's Time Spent Outdoors, Objectively Measured Physical Activity and Overweight. Int J Obes. 2008; 32(11): 1685.
(124) Ekelund U, Brage S, Froberg K, Harro M, Anderssen SA, Sardinha LB, et al. Tv Viewing and Physical Activity Are Independently Associated with Metabolic Risk in Children: The European Youth Heart Study. PLoS Med. 2006; 3(12): e488.
(125) Meyer U, Bloesch T, Peterhans E, Zahner L, Puder JJ, Schindler C, et al. Combined Impact of Health Behaviours on Cardiovascular Risk in Children: A Prospective Study. Oral presentation. Annual Congress of the European College of Sports Science (ECSS); Liverpool (GB), June 2011.
(126) Durlak JA, DuPre EP. Implementation Matters: A Review of Research on the Influence of Implementation on Program Outcomes and the Factors Affecting Implementation. Am J Community Psychol. 2008; 41(3-4): 327.
(127) McKenzie TL, Stone EJ, Feldman HA, Epping JN, Yang M, Strikmiller PK, et al. Effects of the Catch Physical Education Intervention: Teacher Type and Lesson Location. Am J Prev Med. 2001; 21(2): 101.

Curriculum Vitae

CURRICULUM VITAE

Name	Ursina Meyer
Date of Birth	11.07.1982
Nationality	Switzerland

EDUCATION

2009 to present	PhD study program Institute of Exercise and Health Sciences, University of Basel & Swiss Tropical and Public Health Institute, Switzerland Head of faculty: Prof. Dr. Arno Schmidt-Trucksäss Supervisors: PD Dr. Susi Kriemler, PD Dr. Jardena Puder External expert: Prof. Dr. Willem van Mechelen
2006 – 2008	Master of Science in Human Movement Sciences Institute for Human Movement Sciences and Sport, Swiss Federal Institute of Technology Zurich, Switzerland
2002 – 2006	Bachelor of Science in Human Movement Sciences Institute for Human Movement Sciences and Sport, Swiss Federal Institute of Technology Zurich, Switzerland

PROFESSIONAL EXPERIENCE

2011 to present	Research Assistant Swiss Tropical and Public Health Institute, Switzerland
2007 – 2011	Research Assistant Institute of Exercise and Health Sciences, University of Basel, Switzerland

THESES

Master thesis	„Effect of a school-based intervention program (KISS) on children's physical activity in different time periods of the school day" (Original title: "Auswirkung eines schulbasierten Bewegungsförder-ungsprogrammes (KISS) auf die körperliche Aktivität von Kindern") Experts: PD Dr. Susi Kriemler, Dr. Roland Müller Institute for Human Movement Sciences and Sport, Swiss Federal Institute of Technonlogy Zurich, Switzerland

AWARDS

2010	Joint meeting of the European Group for Pediatric Work Physiology (PWP) & the North American Society for Pediatric Exercise Medicine (NASPEM): “Student research award for the best oral presentation”; Niagara-on-the-Lake (Can)
2010	Jahrestagung der Deutschen Gesellschaft für Pädiatrische Sportmedizin: “Beste freie Mitteilung”; Potsdam (D)

ACADEMIC TRAINING DURING PHD

Statistics and Epidemiology

2012	Introduction to R (0.75 ECTS); Swiss School of Public Health
2011	Data analysis in Epidemiology (2 ECTS); Master of Epidemiology, University of Basel Advanced Stata programming (1 ECTS); Master of Epidemiology, University of Basel Observational epidemiological studies: advanced methods for design and analysis (2 ECTS); Swiss School of Public Health
2010	Methods in Epidemiology (1 ECTS); Swiss School of Public Health
2009	Multilevel modelling: Analysis of clustered data (1.5 ECTS); Swiss School of Public Health Biostatistik I (3 ECTS); Master of Public Health; Universities of Basel, Bern and Zürich

Research skills

2010	How to pass your research protocol through an ethics review committee (0.25 ECTS); Swiss School of Public Health Media training workshop: communication skills (0.25 ECTS); Swiss School of Public Health Skills workshop: writing a successful National Science Foundation research proposal (0.25 ECTS); Swiss School of Public Health Systematic reviews and meta-analysis: a practical approach (0.75 ECTS); Swiss School of Public Health
2009	Writing a journal article and getting it published (1 ECTS); Swiss School of Public Health Conducting a literature research (0.25 ECTS); Swiss School of Public Health

PUBLICATIONS

Peer-reviewed articles

(1) Meyer U, Roth R, Zahner L, Gerber M, Puder JJ, Hebestreit H, et al. Contribution of Physical Education to Overall Physical Activity. Scand J Med Sci Sports. 2011; [Epub ahead of print].
(2) Kriemler S, Meyer U, Martin E, van Sluijs EM, Andersen LB, Martin BW. Effect of School-Based Interventions on Physical Activity and Fitness in Children and Adolescents: A Review of Reviews and Systematic Update. Br J Sports Med. 2011; 45(11): 923.
(3) Meyer U, Romann M, Zahner L, Schindler C, Puder JJ, Kraenzlin M, et al. Effect of a General School-Based Physical Activity Intervention on Bone Mineral Content and Density: A Cluster-Randomized Controlled Trial. Bone. 2011; 48(4): 792.
(4) Burgi F, Meyer U, Granacher U, Schindler C, Marques-Vidal P, Kriemler S, et al. Relationship of Physical Activity with Motor Skills, Aerobic Fitness and Body Fat in Preschool Children: A Cross-Sectional and Longitudinal Study (Ballabeina). Int J Obes. 2011; 35(7): 937.
(5) Kriemler S, Zahner L, Schindler C, Meyer U, Hartmann T, Hebestreit H, et al. Effect of School Based Physical Activity Programme (Kiss) on Fitness and Adiposity in Primary Schoolchildren: Cluster Randomised Controlled Trial. Br Med J. 2010; 340(feb23 1): c785.
(6) Kriemler S, Puder J, Zahner L, Roth R, Meyer U, Bedogni G. Estimation of Percentage Body Fat in 6- to 13-Year-Old Children by Skinfold Thickness, Body Mass Index and Waist Circumference. Br J Nutr. 2010; 104(10): 1565.
(7) Burgi F, Meyer U, Niederer I, Ebenegger V, Marques-Vidal P, Granacher U, et al. Socio-Cultural Determinants of Adiposity and Physical Activity in Preschool Children: A Cross-Sectional Study. BMC Public Health. 2010; 10: 733.
(8) Niederer I, Kriemler S, Zahner L, Burgi F, Ebenegger V, Hartmann T, et al. Influence of a Lifestyle Intervention in Preschool Children on Physiological and Psychological Parameters (Ballabeina): Study Design of a Cluster Randomized Controlled Trial. BMC Public Health. 2009; 9: 94.
(9) Zahner L, Muehlbauer T, Schmid M, Meyer U, Puder JJ, Kriemler S. Association of Sports Club Participation with Fitness and Fatness in Children. Med Sci Sports Exerc. 2009; 41(2): 344.

Non-peer-reviewed articles

(1) Moses S, Meyer U, Puder JJ, Roth R, Zahner L, Kriemler S. Das Bewegungsverhalten Von Primarschulkindern in Der Schweiz. Schweizerische Zeitschrift für «Sportmedizin und Sporttraumatologie». 2007; 55(2): 62.

Conference abstracts

(1) Meyer U, Roth R, Zahner L, Gerber M, Puder JJ, Kriemler S. Physical Activity Levels During Physical Education Lessons and Their Contribution to Total Physical Activity. Oral presentation. Conference of the European Group for Pediatric Work Physiology (PWP); Mawgan Port (GB), September 2011.
(2) Meyer U, Bloesch T, Peterhans E, Zahner L, Puder JJ, Schindler C, et al. Combined Impact of Health Behaviours on Cardiovascular Risk in Children: A Prospective Study. Oral presentation. Jahrestagung der Schweizerischen Gesellschaft für Sportmedizin; Lausanne (CH), October 2011.
(3) Meyer U, Roth R, Zahner L, Gerber M, Puder JJ, Kriemler S. Physical Activity Levels During Physical Education Lessons and Their Contribution to Total Physical Activity. Oral presentation. Jahrestagung der Schweizerischen Gesellschaft für Sportmedizin; Lausanne (CH), October 2011.
(4) Meyer U, Roth R, Zahner L, Gerber M, Puder JJ, Kriemler S. Physical Activity Levels During Physical Education Lessons and Their Contribution to Total Physical Activity. Poster presentation. Swiss Public Health Conference; Basel (CH), August 2011.
(5) Meyer U, Bloesch T, Peterhans E, Zahner L, Puder JJ, Schindler C, et al. Combined Impact of Health Behaviours on Cardiovascular Risk in Children: A Prospective Study. Swiss Public Health Conference; Basel (CH), August 2011.
(6) Meyer U, Zahner L, Schindler C, Hartmann T, Hebestreit H, Brunner-La Rocca HP, et al. Key Issues of Success in a School-Based Pa Programm in Primary School Children. Invited speak. ECSS Pre Conference Symposium "Physical Activity and Sedentary Behaviour Intervetnions for Children and young People"; Liverpool (GB), June 2011.
(7) Meyer U, Bloesch T, Peterhans E, Zahner L, Puder JJ, Schindler C, et al. Combined Impact of Health Behaviours on Cardiovascular Risk in Children: A Prospective Study. Oral presentation. Annual Congress of the European College of Sports Science (ECSS); Liverpool (GB), June 2011.
(8) Meyer U, Peterhans E, Bloesch T, Zahner L, Puder JJ, Schindler C, et al. Combined Impact of Health Behaviours on Aerobic Fitness in Children: A Prospective Study. Poster presentation. ECSS Pre Conference

Symposium "Physical Activity and Sedentary Behaviour Intervetnions for Children and young People"; Liverpool (GB), June 2011.

(9) Meyer U, Bloesch T, Peterhans E, Zahner L, Puder JJ, Schindler C, et al. Combined Impact of Health Behaviours on Cardiovascular Risk in Children: A Prospective Study. Poster presentation. ECSS Pre Conference Symposium "Physical Activity and Sedentary Behaviour Intervetnions for Children and young People"; Liverpool (GB), June 2011.

(10) Meyer U, Bloesch T, Peterhans E, Zahner L, Puder JJ, Schindler C, et al. Combined Impact of Health Behaviours on Cardiovascular Risk in Children: A Prospective Study. Poster presentation. Jahrestagung der Sportwissenschaftlichen Gesellschaft der Schweiz; Lausanne (CH), March 2011.

(11) Meyer U, Roth R, Zahner L, Gerber M, Puder JJ, Kriemler S. Physical Activity Levels During Physical Education Lessons and Their Contribution to Total Physical Activity. Poster presentation. Jahrestagung der Sportwissenschaftlichen Gesellschaft der Schweiz; Lausanne (CH), March 2011.

(12) Meyer U, Bloesch T, Peterhans E, Zahner L, Puder JJ, Schindler C, et al. Combined Impact of Health Behaviours on Cardiovascular Risk in Children: A Prospective Study. Oral presentation. Joint meeting of the European Group for Pediatric Work Physiology (PWP) & the North American Society for Pediatric Exercise Medicine (NASPEM); Niagara-on-the-lake (Can), September 2010. Student research award for best presentation.

(13) Meyer U, Zahner L, Puder JJ, Rizzoli R, Kriemler S. The Success of a General School-Based Physical Activity Intervention on Bone Mineral Content Depends on Pubertal Stage but Not on Gender. Poster presentation. Jahrestagung der Sportwissenschaftlichen Gesellschaft der Schweiz; Zürich (CH), March 2010.

(14) Meyer U, Zahner L, Puder JJ, Rizzoli R, Kriemler S. The Success of a General School-Based Physical Activity Intervention on Bone Mineral Content Depends on Pubertal Stage but Not on Gender. Oral presentation. Jahrestagung Deutsche Gesellschaft für Pädiatrische Sportmedizin; Potsdam (D), February 2010. Award: Beste freie Mitteilung.

(15) Meyer U, Zahner L, Puder JJ, Rizzoli R, Kriemler S. The Success of a General School-Based Physical Activity Intervention on Bone Mineral Content Depends on Pubertal Stage but Not on Gender. Oral presentation. Conference of the European Group for Pediatric Work Physiology (PWP); Le Touquet-Paris (F), September 2009.

(16) Meyer U, Zahner L, Puder JJ, Rizzoli R, Kriemler S. The Success of a General School-Based Physical Activity Intervention on Bone Mineral Content Depends on Pubertal Stage but Not on Gender. Poster presentation. Annual Congress of the European College of Sports Science (ECSS); Oslo (N), June 2009.

(17) Meyer U, Zahner L, Puder JJ, Rizzoli R, Kriemler S. The Success of a General School-Based Physical Activity Intervention on Bone Mineral Content Depends on Pubertal Stage but Not on Gender. Oral presentation. Jahrestagung der Schweizerischen Gesellschaft für Pädiatrie; St. Gallen (CH), June 2009.

(18) Meyer U, Kriemler S, Zahner L, Schindler C, Puder JJ. A School-Based Physical Activity Program Increases Fitness and Decreases Adiposity in Primary School Children (Kiss): A Cluster-Randomized Trial. Poster presentation. Jahrestagung der Sportwissenschaftlichen Gesellschaft der Schweiz; Bern (CH), February 2009.

(19) Meyer U, Zahner L, Puder JJ, Roth R, Kriemler S. Effect of a School-Based Physical Activity Intervention Program (Kiss) on Children's Physical Activity in the Segmented School Day. Poster presentation. Annual Congress of the European College of Sports Science (ECSS); Estoril (P), July 2008.

(20) Meyer U, Moses S, Roth R, Puder JJ, Zahner L, Kriemler S. Variationen in den Wochentagen bei der Aktivitätsmessung (MTI) bei Schulkindern existieren und sind relevant. Oral presentation. Jahrestagung der Deutschen Gesellschaft für Pädiatrische Sportmedizin; Ludwigsburg (D), February 2007.