Physical activity in preschoolers

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Summary

Summary

The health benefits of physical activity are clearly established. Physical activity is also thought to be beneficial for children, although morbidity and mortality are established only later in life. One of the most important benefits of physical activity is maintaining a healthy weight and it thus contributes to prevent the development of obesity. However, physical activity is also thought to be related to both aerobic fitness, a strong predictor of cardiovascular disease, and to different motor skills. As there is a gap on research investigating those relationships in preschool children, cross-sectional and longitudinal analyses were done to examine children's physical activity behaviours and their correlates. In addition, it was analysed if physical activity is associated with socio-cultural characteristics. Finally, the effects of a physical activity intervention on adiposity and fitness were evaluated, especially in preschoolers of migrant or low educated families.

This research is based on the Ballabeina Study, a multidimensional lifestyle intervention study aimed at reducing BMI and increasing fitness in preschool children. The cluster-randomized trial was conducted in German and French speaking regions in Switzerland with a high prevalence of migrant populations. The intervention targeted four lifestyle behaviours during one school year: an increase in physical activity, a balanced nutrition, sufficient sleep and a reduction in media use.

In the cross-sectional analyses, substantial differences in physical activity and in adiposity were found between the German and French speaking part of Switzerland. On the other hand, parental socio-cultural characteristics (migrant status or educational level) had less impact on physical activity and adiposity. The cross-sectional analyses also revealed a relationship between physical and body fat, aerobic fitness and motor skills. The cross-sectional analyses also revealed a relationship between physical and body fat, aerobic fitness and motor skills. The longitudinal analyses also showed an association of baseline physical activity with prospective changes in aerobic fitness and in motor skills, but not in body fat. These findings contribute to the current understanding of the relationships of physical activity with fitness and adiposity and strengthen the benefits of being active from early childhood.

The intervention led to improvements in aerobic fitness, but not in BMI, the two primary outcomes. It also led to improvements in body fat and agility. In view of the substantial decrease in children's fitness and the increase in obesity over the last 20 years, the improvements in aerobic fitness and in body fat in favor of the intervention group are most relevant. Moreover, children of migrant or low educated parents benefitted equally from the intervention compared to their respective counterparts. These results are encouraging, as these children have been less accessible in previous interventions. Thus, using strategies to target a multicultural population might represent a promising approach to reduce body fat and increase fitness in these high-risk groups. In conclusion, Ballabeina is an intensive intervention, but offers an effective school-based intervention program to reduce body fat and increase fitness in preschool children.

Zusammenfassung (summary in German)

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Der gesundheitliche Nutzen von körperlicher Aktivität ist unbestritten. Dies gilt auch für Kinder, auch wenn sich die positiven Effekte meist erst im späteren Leben zeigen. Körperliche Aktivität ist wichtig, um ein gesundes Körpergewicht zu halten und dadurch einen Beitrag zur Übergewichtsprävention zu leisten. Körperliche Aktivität scheint aber auch mit aerober Ausdauer, einem wichtigen Einflusswert für kardiovaskuläre Krankheiten, und mit motorischen Fertigkeiten assoziiert zu sein. Da diese Zusammenhänge im Vorschulalter noch nicht ausreichend untersucht worden sind, haben wir die körperliche Aktivität von Vorschulkindern und dessen Wechselbeziehungen mit Adipositas und Fitness genauer unter die Lupe genommen. Zudem haben wir untersucht, inwiefern körperliche Aktivität und Adipositas mit sozio-kulturellen Faktoren assoziiert sind. Schlussendlich haben wir auch die Effekte einer schulbasierten Intervention in Bezug auf Adipositas und Fitness evaluiert, speziell bei Kindern aus Familien mit Migrationshintergrund oder tiefem Bildungsniveau.

Die Grundlage dieser Forschungsarbeit bildet die Ballabeina Studie, eine in der Schweiz durchgeführte Interventionsstudie bei Kindergartenkindern. Diese cluster-randomisierte Studie wurde in Regionen mit einem hohen Ausländeranteil in der Deutschschweiz sowie in der Romandie durchgeführt. Ziel der Studie war, den BMI zu senken und die aerobe Fitness zu verbessern. Die vier wichtigsten Elemente der Intervention waren: eine Erhöhung der täglichen Aktivität, eine ausgewogene Ernährung, genügend Schlaf und eine Reduktion des Medienkonsums.

Die Querschnittuntersuchungen zeigten, dass körperliche Aktivität mit Körperfett, Ausdauer und motorischen Fertigkeiten assoziiert war. Dabei stellten wir bedeutende Unterschiede in Bezug auf körperliche Aktivität und Adipositas zwischen der Deutschen und Französischen Schweiz fest. Auf der anderen Seite schienen elterliche Merkmale wie Migrationshintergrund oder Bildungsniveau weniger Einfluss auf diese Parameter zu haben. In den Längsschnittuntersuchungen konnten wir einen Zusammenhang zwischen körperlicher Aktivität und Verbesserungen in der Fitness aufzeigen, jedoch nicht beim Körperfett. Diese Erkenntnisse entsprechen früher gefundenen Zusammenhänge von körperlicher Aktivität, Adipositas und Fitness und unterstreichen somit die Wichtigkeit, bereits im frühen Kindesalter körperlich aktiv zu sein.

Die Intervention führte zu einer Verbesserung der aeroben Fitness, nicht aber zu einer Reduktion des BMI's. Zusätzlich erzielten wir eine Abnahme des Körperfetts und eine Verbesserung bei den motorischen Fertigkeiten. Da die Fitness bei Kindern über die letzten 20 Jahren stetig abgenommen und das Übergewicht stetig zugenommen hat, sind diese positiven Resultate besonders wichtig. Darüber hinaus konnten Kinder aus Familien mit Migrationshintergrund oder tiefem Bildungsniveau ebenso viel von der Intervention profitieren wie alle anderen Kindern. Dies ist besonders betonenswert, da diese Kinder in früheren Interventionen weniger erreicht werden konnten. Der Ansatz, eine multikulturelle Population einzubeziehen, stellt einen vielversprechenden Lösungsansatz dar, um Übergewicht und Fitness auch bei benachteiligten Kindern zu verbessern. Schlussfolgernd kann gesagt werden, dass Ballabeina ein intensives, aber erfolgreiches schulbasiertes Interventionsprogramm darstellt, mit welchem Körperfett und Fitness von Kindergartenkindern verbessert werden kann.

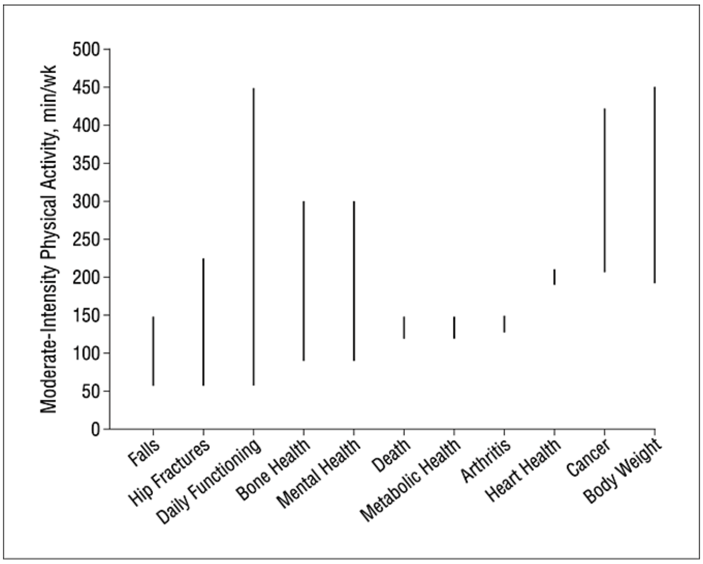
Introduction

1. Introduction

1.1. Health benefits of physical activity

"Physical activity is an investment that pays multiple health dividends"[1]. This statement reflects the strong scientific evidence regarding the importance of physical activity for health (Figure 1). On the other side, low physical activity is a strong predictor of coronary heart disease and all-cause mortality[2,3]. Therefore, guidelines for physical activity in adults were provided, recommending 30 minutes of moderate activity on most days of the week or 20 minutes of vigorous exercise three or more times per week[4,5]. As an example, a longitudinal study showed that engaging in physical activity of at least moderate intensity for more than three hours per week was associated with a 27% decreased risk in mortality[4]. Moreover, following the recommendations for vigorous exercise of 20 minutes three or more times per week was related to a 32% reduction in mortality risk[4]. Physical activity has also been found to be beneficial across a wide array of chronic diseases, such as type 2 diabetes mellitus, cancer, mental health, osteoporosis and hip fractures[1] . It has been shown to be protective against the development of the metabolic syndrome, including central overweight or obesity, disturbed insulin and glucose metabolism and frank diabetes, hypertension and dyslipidemia[6]. The metabolic syndrome with its clustering of cardiovascular risk factors predicts type 2 diabetes, cardiovascular disease and all-cause mortality and has become a major health challenge in adult populations[7].

Figure 1 Health benefits of physical activity:
The needed amount of moderate physical activity to reach health benefits across chronic diseases.



Fulton, J. E. et al. Arch Intern Med 2009;169:2124-2127.

Physical activity is also thought to be beneficial for children, although morbidity and mortality are often established only later in life[8,9]. Nevertheless, regular physical activity in childhood and youth has the potential to reduce the incidence of chronic diseases manifested in adulthood.

Already in childhood, a clustering of metabolic risk factors, including overweight, insulin resistance, hypertension and dyslipidemia, has been noted[10] and the clustered appearance of these factors is directly related to the development of fibrous plaques in the coronary arteries[11]. Low levels of physical activity as well as low aerobic fitness as indirect surrogate of physical activity independently contribute to the presence of the metabolic syndrome[7,10,12]. Thereby, the relationship between physical activity and the metabolic risk appears even stronger in children with low aerobic fitness[10]. Furthermore, physical activity leads to an increase in bone health in children of both genders, particularly before puberty[13] and has been shown to have a positive impact on mental health and academic achievements[14-16].

Therefore, this thesis focuses on the relevance of physical activity for health in children and on strategies to increase physical activity. It has a particular focus on the benefits of physical activity on adiposity, aerobic fitness and motor skills in preschool children, as well as on differences in physical activity due to socio-cultural parameters. Furthermore, the efficacy of a preschool-based physical activity intervention on adiposity and fitness has been investigated, with a particular interest in the more high-risk group of children of migrant or low educated families.

Physical activity and body fat

Even in young children, overweight and obesity have been increasing dramatically worldwide[17,18]. Despite a possible stabilization, the high prevalence remains a great public health concern[19,20]. One of the most important benefits of physical activity is maintaining a healthy weight and it thus contributes to prevent the development of obesity[1]. A review concluded that high levels of physical activity are probably protective against childhood obesity[21]. As obese children are at risk of becoming obese adults[22,23], it is essential to investigate the relationship between physical activity and adiposity starting in early childhood.

In line with these statements, previous cross-sectional studies in children reported that lower levels of physical activity were related to a higher risk of being obese[21,24]. Thereby, some authors described a stronger inverse association of more vigorous activities with body fat[25,26]. However, these data do not clarify the intensity necessary to achieve a beneficial response in body fat. In addition, the cross-sectional designs do not establish whether low levels of physical activity cause excess weight gain or whether overweight children are less likely to engage in physical activity[24]. In contrast, the evidence for a prospective association between physical activity and the risk of developing obesity from intervention and observational studies is less clear[24] and more research in this topic, especially in younger children, is needed[21]. The few longitudinal studies in young children showed controversial results regarding the relationship between physical activity and body fat. Some[27,28], but not all [29] of these studies could demonstrate an inverse association between physical activity and increases in body fat. A recent review concluded that objectively measured total physical activity may not be a key determinant of body fat gain and that the direct impact of physical activity on weight control should not be overestimated[24]. However, to further elucidate the complex relationships between physical activity and adiposity, more studies with precisely measured subcomponents of physical activity, such as the impact of moderate or vigorous activities, are needed.

Beside low levels of physical activity, high levels of sedentary behaviours (predominantly in the form of screen time) are also related to adiposity[30-32]. Sedentary behaviours are distinct and independent from physical activity behaviours and they are likely to have independent effect on weight and health indicators[31,32]. Analyses of evidence from cross-sectional, longitudinal and intervention studies have shown primarily consistent associations between screen time and overweight/obesity in children[31-33]. This relationship appears even stronger in preschool children[8,34-36]. However, the clinical relevance of this significant, but small positive relationship between screen time and body fatness in children is uncertain[33].

Physical activity and aerobic fitness

The association of physical activity and aerobic fitness in children has been studied in previous cross-sectional studies and revealed weak to moderate correlations[26,37,38]. Thereby, the cross-sectional relationship between vigorous physical activity and fitness seem to be stronger than those between total physical activity and fitness[26,39-42]. As physical activity is normally thought to be closely related to aerobic fitness, the rather weak correlations have risen some debates and the often inaccurate assessment of physical activity has been criticised[12].

Only few studies investigated the longitudinal association between physical activity and aerobic fitness in children[12,43] and these data seem to support the conclusions reached by the previous cross-sectional studies. A longitudinal study in 9 to 15 years old children confirmed the earlier findings of a generally weak to moderate association between objectively measured physical activity and aerobic fitness[12]. Other data in school children pointed also to an association of physical activity with changes in aerobic fitness over time. In Hungarian school-aged boys, the decrease in habitual physical activity between 1975 and 2005 was accompanied by a decrease in aerobic fitness[44]. Similarly, high levels of physical activity in school children were associated with a better aerobic fitness 4 years later[43]. Adolescents who were less active at baseline, but subsequently increased their PA levels over the next four years, never reached the fitness performances of children who were active at baseline. This hints to the importance to be physically active starting in early childhood. However, there is still a need for longitudinal studies investigating the influence of physical activity on aerobic fitness, particularly in preschool children.

Physical activity and motor skills

Previous cross-sectional studies in preschoolers described positive associations between physical activities and different motor skills[45-47]. Based on these studies, it has been hypothesized that performance level in motor skills may predict physical activity. But as these studies represent cross-sectional data[45-47], it is difficult to draw conclusions about the direction of causality. Stodden et al.[48] described in their model that physical activity and motor skills in children underlie a reciprocal and dynamic relationship, which is mediated by factors such as aerobic fitness and obesity. Although, the relationship between physical activity and motor skills is still weak in early childhood, it may strengthen over time[48]. In contrast to previous data, in the model of Stodden et al., they assumed that young children's physical activity might drive their development of motor skill competence[48]. Thereby, increased physical activity levels provide opportunities to improve motor skill competences.

Longitudinal studies in preschoolers are lacking. Longitudinal studies in school children showed controversial data about the relationship between motor skills and physical activity[49-51]. Furthermore, it remains unclear, if children with high levels of motor skill performance are more likely to engage in physical activity later in life or whether high active children improve their motor skills and therefore maintain high levels of physical activity. Therefore, more prospective data are needed to clarify the relationship between physical activity and motor skills.

1.2. Epidemiological aspects

Secular trends of physical activity

Although there are no population-level studies on changes in objectively measured physical activity in children over the last decades, the few existing data indicate a secular decline in reported physical activity[52]. As long-term changes in physical activity patterns might result in fitness changes, the known secular decreases in fitness levels of children could thus serve as surrogate marker of the decrease in physical activity[53]. Physical activity, fitness and fatness interact in many possible ways, and therefore, the decrease in fitness could also be explained by the increase in fatness[54,55]. It seems natural that fatter children will perform worse on fitness tests[54,56]. However, the decrease of aerobic fitness in children has been shown to be also independent of the increased weight[54]. Therefore, it seems more appropriate that fitness performance has declined because children are less active than in the past[54,57]. Indeed, some data suggest that children have become less physically active and that sport participation rates in children have been decreasing[52,57,58]. Yet, surprisingly little is known about the timing, nature and magnitude of changes in physical activity levels in childhood[30]

Based on the actual literature, two main potential factors may be implicated in this decrease of physical activity. First, an increase of sedentary behaviours in children over the past 20-30 years has been well documented[32,59,60] and is thought to displace physical activity. It has been reported that 3-5-year old children spend around 80% of their time in activities classified as sedentary or at most light physical activity[8,60]. Sedentary behaviour generally includes television viewing, electronic games and computer use. However, these behaviours may not be the only surrogate markers of sedentary behaviour[61]. As most previous studies used subjective methods to measure sedentary behaviour, altogether, little is known about longitudinal changes in objectively measured sedentary behaviour[30].

Second, the amount of time spent outdoors is a potentially crucial environmental influence on children's physical activity. Children living in neighbourhoods where outdoor physical activity is restricted by climate, safety, or lack of space, are at increased risk to be less physically active[9]. Indeed, playing outdoors was consistently associated with higher levels of physical activity in children[62] and has been shown to be a potential determinant of physical activity in young children[62-64]. Longitudinal data showed significant declines in time spent outdoors among boys and girls over a 5-year period[65]. However, factors that influence changes in children's time spent outdoors are poorly understood and it remains unknown which features of the neighbourhood environment are the most important[62,65]. The inconsistent results from previous studies may depend on the assessment method (perceived vs. objective) of environmental characteristics[62]. Self-reports of environmental factors represent *perceived* rather than *real* features of the physical, socio-cultural, economic and political environments and little is known about the accuracy of such perceived features[66]. It remains unclear whether environmental factors were more important predictors of changes in time spent outdoors or if individual and social factors play a more important role[65,67]. Generally, individual and social factors like children's preferences or the role of parents (time that parents allow their children to spend outdoors, encouragement, and supervision) do influence physical activity behaviour. However, environmental factors such as the advancing urbanisation (increased traffic or lack of space and attractive opportunities for outdoor play) or the neighbourhood crime incidence and safety are also impacting time spent playing outdoors and therefore physical activity, but further research is needed to clarify this relationships[62,65].

Regional differences in physical activity

There exist large variations in the levels of physical activity and sedentary behaviour in youth across European countries[68]. The percentage of children who reported to participate in 60 or more minutes of physical activity on at least 5 days per week ranged from 47% (Ireland) to 19% (France)[68]. Comparing these data across Europe, a North-South-decline has been observed. Children in south-western European countries tend to be less active than those from north-eastern countries. Analogical trends have been observed for other health related behaviours and obesity[68-70]. Similar to this European North-South-decline, differences in physical activity levels between different socio-cultural and linguistic regions have been reported even within Switzerland[71,72]. Therefore, the large neighbourhood environment, including both the large socio-cultural and the physical environment seems to play an important role in determining physical activity behaviours. As will be discussed below, these data have to be considered with caution, since physical activity was assessed solely by subjective means of questionnaires.

Socio-cultural differences in physical activity

Children from ethnic minorities or children living in poverty are more at risk to be physically inactive[9,73,74]. Moreover, obesity prevention studies in these populations seem to be less effective[75-79]. Although there is evidence for socio-cultural differences in physical activity[80-84], the literature that might explain reasons for this phenomenon is scarce[81]. The debates on ethnic and on socio-economic causes for differences in health are closely connected[81] and therefore it is difficult to tease out socio-economic from socio-cultural or ethnicity factors. Indeed, there is evidence that the lower health situation of migrants is predominantly due to a lower socio-economic status[85-87] and that the socio-economic situation of the parents may play an important role in the development of health related behaviours, such as physical activity and sedentary behaviours[21,73,88,89]. However, many countries have examples of minority groups that are not economically disadvantaged which unfortunately do not get much attention from the public health field[81]. Consequently, it is hardly impossible to separately assess impact of socio-economic status on ethnic differences in physical activity behaviour[81].

The few existing literature assessing reasons for poorer health or health behaviours in this populations suggests that education influences knowledge and beliefs, occupation has an effect on lifestyle and shared peer values, and income is related to access to resources[90]. Other mentioned factors are the unsuitable living conditions and infrastructure[91], a greater illiteracy[91], a limited access to information or health care[85] and poorer ability to use the available resources[85], the perception of their health, and more barriers to get care[81]. Therefore, more attention should be paid on these high-risk groups.

1.3. Definitions of socio-cultural characteristics

As described above, some socio-cultural characteristics (such as migrant or a low socio-economic status) are associated with a lower health and are therefore considered high-risk groups for the development of inactivity and other health related behaviours[81,87]. As one focus of this thesis was to assess differences in physical activity according to socio-cultural characteristics and to investigate the impact of the intervention on these two high-risk groups, the selected population will be described in the following paragraphs.

Migrant status

As health inequalities between minorities and the general population have been well described[81,87,91] minority populations have been and remain an important focus in the field of public health. Thereby, several terms are used to describe these populations. US studies mainly use the term "ethnic minorities" as they mostly investigated Black, Hispanic or Asian minority populations[92-94], while in European studies the terminology of "migrants" is used to deal with a multicultural, mostly migrant population[75,95]. Various definitions of migrant status exist, but one of the most established definitions is the following: Migrants are individuals who remain outside their usual country of residence for at least one year[96,97]. A categorization of migrant status according to the country of birth is also very frequently used and is easy to use when large populations are studied. The differences in terminology between the US and Europe demonstrate the disparities between the respective continents as "ethnic minorities" reflect US conditions and "migrants" are referred to a population of various cultural backgrounds. In accordance to other European studies[75,95,96,98,99], we used a migrant classification according to parental country of birth. We considered children migrants if at least one parent was born outside of Switzerland[22,95,98].

Educational level

The socio-economic status is a complex construct and often composed of education, income, wealth or occupation[87,100]. As we were not allowed to collect data about income and wealth in our study, parental educational level served as a proxy for the socio-economic status[101]. Indeed, the educational level is a proxy and one of the strongest predictor of socio-economic status[102,103]. Furthermore it can be measured easily and is attained early in life, associated with income and occupation, and rarely affected by health impairments[87]. In our study, educational level was determined by the respective highest grade of school completed and a low educational level was defined as at least one parent with no education beyond mandatory school (9 years).

1.4. Methodological aspects of physical activity assessment

Measurement of physical activity

Physical activity is a complex behaviour and it is challenging to measure it accurately. However, an accurate measurement of habitual physical activity is fundamental to study the relationship between physical activity and health[104]. Indirect measures, such as self-reported questionnaires, are the most common and feasible method to measure physical activity at a population level[105]. These methods are often used due to their practicality, low cost, low participant burden, and general acceptance[105]. However, self-reported methods possess several limitations in terms of their reliability and validity[106]. It has been reported that indirect and direct measures are not necessarily highly correlated and that there is a tendency to overestimate the amount of physical activity measured by these indirect methods[105]. Furthermore, questionnaires for young children rely on proxy reports and seem to be less practicable to assess the characteristic sporadic and short bursts of physical activity in children[107].

Objective measures overcome some of the problems of measuring physical activity in children. They are believed to offer more robust estimates as they remove recall or response bias. Direct measures include doubly labelled water, direct and indirect calorimetry, physiologic markers (i.e. heart rate or respiratory rate), motion sensors (i.e. accelerometers, pedometers) and direct observations. Despite the advantages of objective methods, these measures are often time-consuming, expensive, intrusive and burdensome, and it has been suggested to be difficult to apply in large epidemiologic settings[105].

Monitoring technologies like accelerometers or pedometers provide more detailed information on the activity and inactivity behaviour as well on the movement frequency, duration or intensity. In population-wide studies, accelerometers are considered to represent a good trade-off between accuracy and feasibility for assessing physical activity[108-111]. As a result, accelerometry-based monitors have become very popular to assess physical activity in children[105,107,112].

Accelerometry

Accelerometers can measure acceleration in one to three axes and usually, they are worn on the hip. These accelerometers produce output in counts per unit time (epoch). Epochs represent the sampling interval. Older studies have tended to use 1-minute epochs, but in preschool children, it is suggested that shorter epochs (15 seconds or lower) would be more appropriate, as children’s patterns of physical activity are highly intermittent[112-114]. Shorter epochs allow the capture of the sporadic bursts of activity observed in children[115]. The recorded epochs must be converted in constructs such as time spent in moderate-to-vigorous activity or time spent sedentary. To measure the amount of time spent in activities of moderate-to-vigorous intensity or the amount of sedentary behaviour, accelerometer counts are interpreted using cut-points derived from calibration studies. Several studies involving preschool children have attempted to calibrate accelerometer counts to units of energy expenditure (oxygen consumption), Metabolic Equivalent of Tasks (METs) or directly observed intensity classifications[113,114,116,117]. Despite the variability in the recommended cut-points to classify activities by intensity, some of these studies showed good correlations between accelerometer counts and oxygen consumption during structured and free play physical activity in preschoolers[113,114].

In our study we used the accelerometers of Actigraph (GT1M, USA, Florida), which is a widely used device and has the greatest body of consistent and high-quality evidence to support its use[111]. These devices are unidirectional and only sensitive in the vertical axis. We recorded our data in 15-seconds sampling intervals (epochs), as proposed for preschool children[112-114]. We chose the cut-points published by Pate et al. which have been validated for 3-5 years old children[113]. They used the following cut-points: moderate physical activity (MPA) 420-841 counts per 15 seconds and vigorous activity (VPA) ≥ 842 counts per 15 seconds.

Limitations of accelerometry

There are some limitations in measuring physical activity in children by accelerometers. As described above, many threshold counts have been developed by different research groups over the past ten years to classify activities by intensity in young children. However, there is still a lack of consensus on the most suitable cut-points and the choice of accelerometer cut-points can result in large discrepancies between studies[108].

Furthermore, it is possible that current studies have overestimated the precision of objective measurement in children by relying on a single period of measurement that may not represent habitual physical activity. Physical activity levels in children change over time, vary by season and showed a large intraindividual variability[107]. Moreover, a low measurement precision has been reported regarding swimming and the extensive use of “gliding activities” on bikes, scooters or roller skates[118].

Another problem concerns the compliance. If children do not wear the monitors consistently during a measurement period, the data have insufficient explanatory power. Furthermore, comparability between studies is limited by the lack of standardization of protocols for the use of accelerometers as well for the cleaning and the analysis of accelerometer data[111].

1.5. Physical activity interventions

In preschoolers, there exist seven randomized controlled physical activity intervention trials aiming to reduce either BMI or body fat [76,93,94,119-122]. Only two of them included also physical activity as outcome measure[119,122]. Thereby, one study showed a beneficial effect on physical activity (measured by pedometers) in favour of the intervention group[119], while the second study did not lead to significant intervention effects on physical activity (measured by accelerometers)[122]. Of these seven RCTs in preschoolers, three were performed in high-risk group populations[76,93,94]. The studies of Fitzgibbon et al.[93,94] were conducted in Black and Hispanic US minority groups and the study of Nemet et al.[76] was performed in low socio-economic kindergartens in Israel. In all three studies, intervention children attended a physical activity program, but neither of the three studies assessed physical activity as an outcome measure.

In summary, it can be stated that there is a lack of physical activity interventions in preschool children, especially in high-risk groups and in the more multicultural migrant population as seen in Europe. To include these high risk groups, it is important to integrate any health promotion programs in the context of the broader social and cultural values to develop effective approaches[123-125].

1.6. Recommendations and policies for physical activity

Since the beginning of the 21th century, numerous recommendations for physical activity in youth exist[1]. In general, organisations recommended either 30 or 60 minutes of daily moderate-to-vigorous activity. In 2002, the guidelines of the National Association for Sport and Physical Education (NASPE) recommended that children should accumulate at least 60 min/day of structured and 60 min/day of unstructured physical activity[126] without specifying the intensity. However, reviews conducted in the same time period concluded that the scientific evidence needed to develop recommendations and provide policies for children, were often lacking and that the recommendations from several organisations may created confusion[1,127].

In 2005, Strong et al. published a systematic review of the effects of physical activity on health outcomes and developed evidence-based recommendations for physical activity in children[23]. They recommended that children should participate every day in at least 60 minutes up to several hours in moderate-to-vigorous physical activity which is enjoyable and developmentally appropriate[23]. Sixty minutes or more of moderate-to-vigorous physical activity on a daily basis is consistent with desired health outcomes[23]. Thereby, the recommended 60 minutes or more of physical activity can be achieved in a cumulative manner in school during physical education, recess, and before and after school programs[23]. If additional beneficial changes in skeletal health, aerobic fitness, muscular strength and adiposity are desired, higher amounts, specific types or intensities of physical activity are necessary. For example, to achieve additional benefits in bone mineral density, high-impact activities are needed two to three times per week. Similarly, to stimulate muscular hypertrophy in adolescence, specialized exercises such as strength/resistance training on two or more times per week will be necessary[23]. However, a later study postulated that even general physical activity levels should be higher than the current recommendations of at least 60 minutes physical activity per day to prevent cardiovascular risk factors[128,129].

This resulted in different policy guidelines for physical activity in children. While Canada's guidelines postulate 90 minutes of at least moderate activity[130], most other countries (including US, UK, Australia) recommend at least 60 minutes per day of moderate-to-vigorous activity[131]. Similarly, also in Switzerland, at least 60 minutes of moderate-to-vigorous activity per day has been recommended for children[132].

In the latest review, Janssen & Le Blanc developed Strong's recommendations further[131]. They confirmed the health benefits of 60 minutes or more of physical activity. As vigorous intensity activities may provide an even greater benefit on health, they recommend that additionally, more vigorous activities should be incorporated in children's physical activity. Aerobic activities that stress the cardiovascular and respiratory systems have the greatest health benefit except for bone health where high-impact weight bearing activities are required[131]. Therefore, aerobic activities should make up the majority of the physical activity and muscle and bone strengthening activities should be incorporated at least three times per week[131]. This has also been confirmed by an actual study, which showed that with several minutes per day of vigorous activities that load bone enough, higher bone mineral content and density, as determinants of bone strength, could be obtained[129,133].

As result of this previous research, the UK presented recently the latest UK-wide physical activity guidelines to ensure consistent messaging[134]. They postulate that children of preschool age should be physically active for at least three hours per day, spread throughout the day. Activities could be of any intensity (light or more energetic) and may include activities which involve movement of all the major muscle groups, energetic play or walking. Furthermore, they recommend that children under five years should minimise the amount of time spent being sedentary for extended periods[134].

1.7. Aim of research

As physical activity is a potentially modifiable health related behaviour, it is of interest to understand its determinants and the nature of its relationship with other health related outcome variables in order to improve children's health. Therefore, this thesis has focused on the following questions:

1. What are the cross-sectional and longitudinal associations between physical activity with body fat, aerobic fitness and motor skills in preschool children?
2. Are there differences in physical activity and in adiposity according to migrant status, educational level or the large socio-cultural neighbourhood environment?
3. Is it possible to reduce adiposity and improve fitness in preschool children with a school-based physical activity intervention?
4. Can children of high-risk subgroups benefit equally from such an intervention?

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Publication 1

Influence of a lifestyle intervention in preschool children on physiological and psychological parameters (Ballabeina): study design of a cluster randomized controlled trial

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Study protocol

Influence of a lifestyle intervention in preschool children on physiological and psychological parameters (Ballabeina): study design of a cluster randomized controlled trial

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Abstract

Background: Childhood obesity and physical inactivity are increasing dramatically worldwide. Children of low socioeconomic status and/or children of migrant background are especially at risk. In general, the overall effectiveness of school-based programs on health-related outcomes has been disappointing. A special gap exists for younger children and in high risk groups.

Methods/Design: This paper describes the rationale, design, curriculum, and evaluation of a multicenter preschool randomized intervention study conducted in areas with a high migrant population in two out of 26 Swiss cantons. Twenty preschool classes in the German (canton St. Gallen) and another 20 in the French (canton Vaud) part of Switzerland were separately selected and randomized to an intervention and a control arm by the use of opaque envelopes. The multidisciplinary lifestyle intervention aimed to increase physical activity and sleep duration, to reinforce healthy nutrition and eating behaviour, and to reduce media use. According to the ecological model, it included children, their parents and the teachers. The regular teachers performed the majority of the intervention and were supported by a local health promoter. The intervention included physical activity lessons, adaptation of the built infrastructure; promotion of regional extracurricular physical activity; playful lessons about nutrition, media use and sleep, funny homework cards and information materials for teachers and parents. It lasted one school year. Baseline and post-intervention evaluations were performed in both arms. Primary outcome measures included BMI and aerobic fitness (20 m shuttle run test). Secondary outcomes included total (skinfolds, bioelectrical impedance) and central (waist circumference) body fat, motor abilities (obstacle course, static and dynamic balance), physical activity and sleep duration (accelerometry and questionnaires), nutritional behaviour and food intake, media use, quality of life and signs of hyperactivity (questionnaires), attention and spatial working memory ability (two validated tests). Researchers were blinded to group allocation.

Discussion: The purpose of this paper is to outline the design of a school-based multicenter cluster randomized, controlled trial aiming to reduce body mass index and to increase aerobic fitness in preschool children in culturally different parts of Switzerland with a high migrant population.

Trial Registration: Trial Registration: clinicaltrials.gov NCT00674544

Background

Obesity is considered to be a global epidemic by the World Health Organization [1]. The marked increase in childhood obesity is alarming and already present in preschool children reaching 26 % in 2- to 5-year old children and to 37 % in 6- to 11-year old children [2]. In Switzerland there is a prevalence of overweight and

obesity of around 20 % and 23 % in 6- to 12-year old boys and girls [3]. The prevalence of overweight/obesity and of physical inactivity is especially increased in children of low socioeconomic status (SES) [4] and/or children of migrant background [5, 6].
Obese children are at increased risk to become obese adults [7, 8] and this tracking becomes stronger the closer the child gets to adult status [9]. Yet, overweight preschool children have an over fivefold risk to be overweight at age twelve years compared with normal weight preschoolers [8]. Childhood obesity is already associated with cardiovascular disease risk factors [10-13] as well as other complications [7, 8] and is an independent predictor of coronary heart disease in adulthood [14].
The main environmental causes attributed to the enormous increase in body fatness in the last few decades are an increase in energy intake through food and a decrease in energy expenditure through a decrease in physical activity (PA) and/or an increase in sedentary behaviour [15]. One of the most important contributors to sedentary behaviour is media use (TV, PC, game use) [16] which is also related to energy intake [16]. Another postulated factor associated with obesity and insulin resistance is a lack of sleep [17]. Social, cultural and economic factors also influence energy balance.
In the last years, cross-sectional and longitudinal data have shown that the increased intake of foods with high fat or sugar content [18], high energy snacks, sweets and sugar-added beverages is associated with increasing BMI [18-20]. In addition, over the last 20 years, aerobic fitness has decreased by around 8 % in children from developed countries [21]. In contrast to aerobic fitness, there are no population-level objective data on temporal changes in total PA. However, some data indicate that children have become less physically active or less engaged in sports participation in the last years [22, 23]. Nowadays, 3- to 5-year old children monitored with accelerometers spent around 80 % of their time in activities of <1100 counts/min [24], which is considered to be sedentary behaviour or at most light PA [25]. In children, physical inactivity and reduced aerobic fitness are associated with increasing prevalence of cardiovascular risk factors [26-28] even independently of weight status [28, 29].
As the great majority of obesity treatment studies show a lack of selected and longstanding effectiveness [30], primary prevention is absolutely essential. But short- and long-term studies in recent reviews show only small or no positive effects in BMI, SF and/or PA [31-34]. Implementing successful studies or projects is even more difficult in children from families of less advantaged SES and/or migrant background [34, 35]. Although the period between the ages four and seven (the timing and the magnitude of the so called obesity rebound) has been suggested as a crucial time for development of overweight and obesity in children, there is a lack of studies in younger children [34]. For these reasons, we developed a study to assess the effect of a multidisciplinary lifestyle intervention on BMI and aerobic fitness by focusing on a young age group (preschoolers) and on children of migrant background (Ballabeina – Kinder im Gleichgewicht / enfants en équilibre). Ballabeina is Rhaeto-Romanic and means swing, teeter-totter, seesaw. This name of the study stands for a life in drive but also in balance.

Theoretical model

Causes for overweight and obesity are multifaceted and prevention is difficult and complex. In the last years, social models of health promotion have been increasingly used to study complex interactions [36, 37], as simple interventions are unlikely to work on their own and the development of effective preventive interventions requires strategies that affect multiple settings simultaneously [38]. Ballabeina is based on the social ecological model [36] **(figure 1)**, that includes concentric rings that influence lifestyle patterns. The "psychobiologic core" of the model represents the genetic, physiologic, and socio-cultural forces that shape ones identity (**individual child**). This core is surrounded by the **microsystem**, the immediate environments with which a child interacts (parents, siblings, teachers, peers, etc.). The **exosystem** includes environments with which the child doesn't usually directly interact, but that can still affect the child (school boards, etc.). The **macrosystem** includes the broad societal settings under which the other cycles function (culture, history, social norms, economic system, etc.). For preschooler, the two main influence factors are the family and the teachers [39]. That's why the main intervention targets included these settings. The program promotes a healthy lifestyle by positively influencing personal, behavioral, and environmental factors. On the one side the intervention program transferred knowledge about adequate PA, nutrition and healthy food selection, reduced media use and proper sleep. On the other side

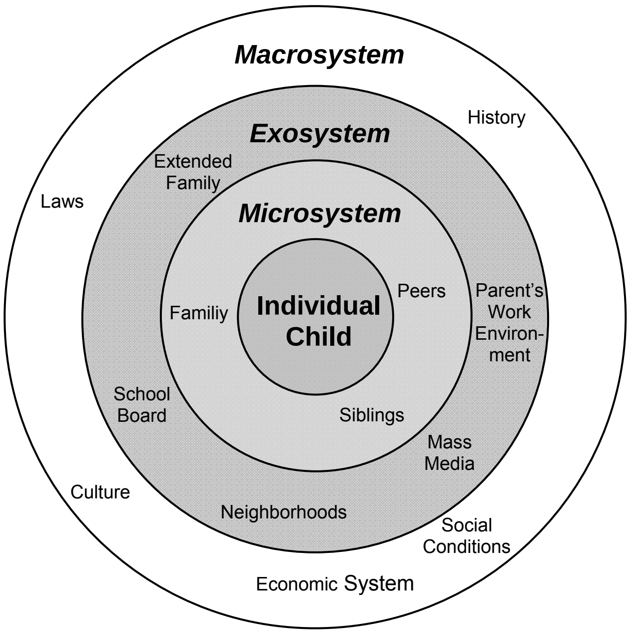


Figure 1: Ecological Model
Bronfenbrenner's Ecological Model describing the environmental influences on a child, with permission from [39].

the intervention also seeked to change the behavior of the child by increasing skills like motor abilities and augmenting daily PA. In addition the children and parents learned in a practical way strategies to change their nutritional behavior according to five nutrition messages (see below). The teachers achieved competencies by implementing PA and nutrition lessons in the preschool. On the environmental level, the built infrastructure (in- and outdoor in preschool) was adapted to enhance the child's natural behaviour to move and to explore. Participation of the children in extracurricular sport activities (club, etc.) in their neighbourhoods was promoted. The Ballabeina team also collaborated with the school boards, the building authorities and the school health services.

Methods/Design

Study objectives

The aim of the study was to evaluate the effects of a multidisciplinary multilevel lifestyle intervention in preschool children (aged 4- to 6-years) during one school-year in a multicenter cluster randomized controlled trial. The study included 40 randomly selected preschool classes and was conducted in the French (canton Vaud, VD) and in the German (canton St. Gallen, SG) part of Switzerland, focusing on areas with a high prevalence of migrant children.

Main outcomes

Primary outcomes:

- BMI
- Aerobic fitness (20 m shuttle run)

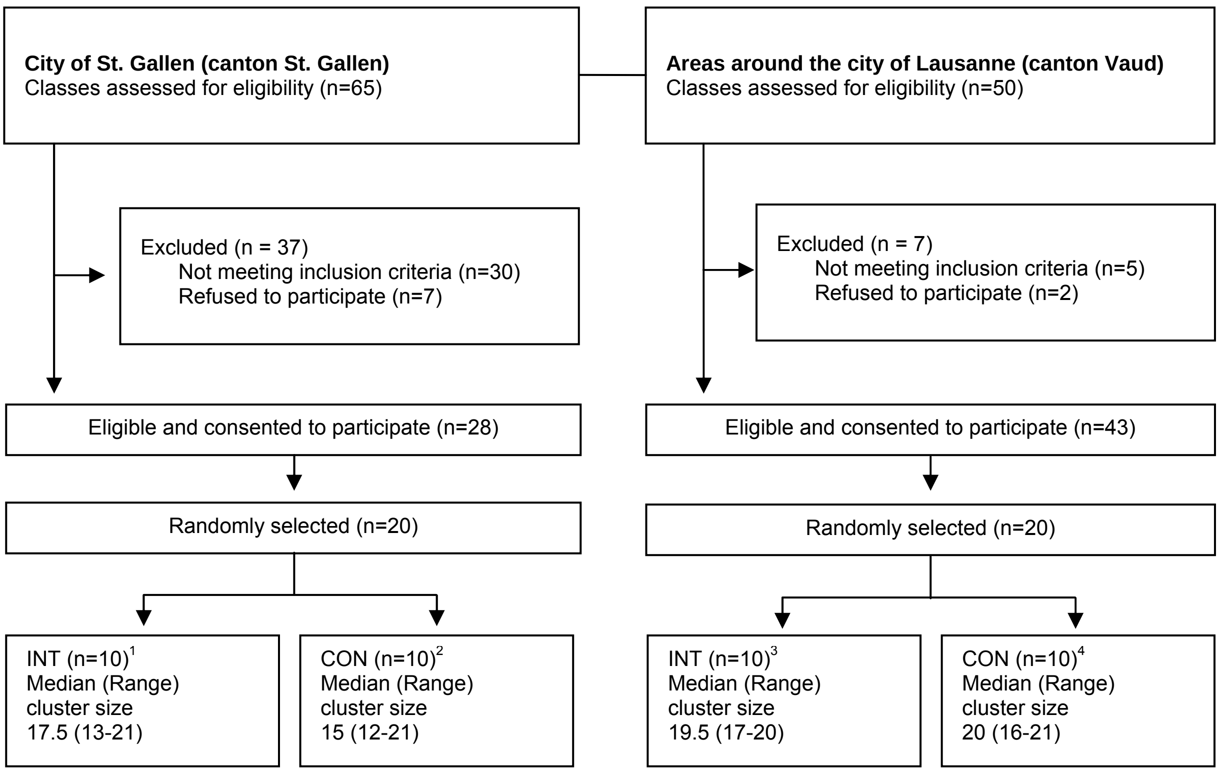
Secondary outcomes:

- Total (sum of four SF, bioelectrical impedance) and central (waist circumference) body fatness
- Other motor abilities (obstacle course, balance platform, balance beam)
- PA and sleep duration (accelerometry and questionnaires), media use, nutritional behaviour and food intake of the child and the family (all questionnaires)
- General health (child and family), health-related quality of life, presence of hyperactivity (all questionnaires)
- Cognition tests (testing attention and spatial working memory ability)

Null-hypothesis: Potential differences in the primary outcomes between the INT and the CON groups at the end of the intervention will be entirely due to chance.

Study Design

Figure 2 shows a flow diagram of the recruited population. It was performed in two (SG & VD) out of 26 Swiss cantons. The German (SG) and the French (VD) parts of Switzerland represent two culturally distinct regions with different school and preschool systems. Classes from SG and VD were therefore separately selected



[1] 8 single preschool classes, 1x2 classes in one school.
[2] 10 single preschool classes.
[3] 3 single preschool classes, 2x2 classes in one school, 1x3 classes in one school.
[4] 4 single preschool classes, 2x3 classes in one school.

Figure 2: Participants flow chart

and randomized after agreement of the school directors and the school health services of both cantons. The city of St. Gallen and the Lausanne area were chosen due to a high prevalence (i.e. at least 40 %) of children of migrant background. Migrant background was defined as at least one parent born out of Switzerland. The prevalence of 40 % was chosen as the school board estimated that in large adjacent areas with a high prevalence of a migrant population, 40-70 % of children were of migrant background. For the selection and randomization opaque envelopes were used. For practical reasons, and to reduce an effect of contamination, preschool classes integrated in the same school building were randomized into the same group.

For all children an informed consent from a parent or a legal representative was necessary in order to participate in the study. Of the 727 children visited the chosen preschools, consent was obtained from parents/legal representatives for 655 (343 in the INT and 312 in the CON, participation rate: 90.1 %).

The study was approved by the cantonal ethical committees of St. Gallen and Vaud.

Need assessment, preplanning and pilot studies

In a first step a broad state of the art of health promoting projects in Swiss preschools [40-44] and a requirement analysis (knowledge, existing offers and barriers) was done. Teachers, health professionals and migrant experts were interviewed and asked to respond to a structured questionnaire. We also interviewed parents of migrant background with special emphasis on nutrition and PA behaviours (Jörg R, unpublished license of diploma, University of Basel). We performed qualitative interviews and designed and distributed questionnaires about their health perception, individual needs and attitudes towards offers in five preschool classes. Physical education classes were visited and analyzed. Based on this analysis, we determined content and transmission of information, as well as the extracurricular offers. We then performed different pilot studies (**table 1**) before the beginning of the main intervention.

Intervention

The intervention was developed with input from exercise physiologists, preschool and primary school teachers, paediatricians, dieticians, psychologists and various stakeholders including experts for migrant families). The intervention focused on four topics: PA, nutrition, media use and sleep duration and was primarily applied at the level of the teachers, children and parents. All INT classes proceeded according to the same curriculum i.e. workshops, lessons, home activities, offers of extra-curricular activities, adaptation of the built infrastructure. The teachers were coached by trained health promoters (HP). These were physical education teachers who were further trained by a dietician and a physician. Theses HP intervened on the level of the teachers, the children, the parents and the local community. The CON group continued to follow their usual school curriculum which included one 45 min physical education lesson taught by the classroom teachers and one 45 min rhythmic lesson (given by a rhythmic specialist) for the French part of the study. Children were blinded to the existence of INT classes.

Table 1: Overview of the different pilot studies:

Pilot studies evaluating the intervention (PI)	Pilot studies evaluating the measurements (PM)
11/2006: Testing of 10 PA home activity cards in 5 preschool classes for 4 weeks. Evaluation by teachers and parents (questionnaires).	
5/2007: Testing of 2 further PA and 2 nutrition home activity cards in 4 preschool classes. Evaluation by teachers and parents (questionnaires).	
11/2007: Testing of daily PA and weekly nutritional lessons with their home activity cards during 3 weeks in 1 preschool class. Evaluation by teachers and parents (questionnaires).	<u>Feasibility and selection of tests</u> 11/2007: Evaluation of 10 motor ability tests in one preschool class and selection of 4 of them by a team of sports scientists. Evaluation of the anthropometric measurements and the cognitive tests.
	<u>Feasibility and reliability of tests</u> 4/2008: Evaluation of the 4 motor ability tests in 2 preschool classes. Test-retest reliability of the balance platform test (static balance) and the anthropometric measurements.
	<u>Reliability of motor ability tests</u> 6/2008: Test-retest reliability of the "obstacle course" test (combined motor ability) and the balance beam test (dynamic balance) 1 preschool class.

The teachers and the parents, however, knew about the intervention arm. Participants, parents and school personnel, including classroom teachers, were informed that the intervention would promote their children's health, but were unaware of the main objectives.

Teachers:

Prior to the intervention, the teachers took part in two afternoon workshops on the four topics (PA, nutrition, media use and sleep). In these workshops the teachers learned how to work with the lessons, the homework cards, the new PA infrastructure material. During the study, regular informal exchanges between the teachers and the HP took place and two formal meetings were organized.

Children:

PA lessons: PA lessons were given four times a week including 40 min lessons and 5 min cool down. In the beginning, one of the four lessons was given by the HP with the regular classroom teachers attending these lessons. After four months of intervention, the HP reduced their contribution to twice a month while the remaining lessons were taken over by the preschool teachers. All PA lessons were prepared by an exercise physiologist. The lessons took place in or around the preschool and once a week in the gym. Training of coordination and endurance was performed as described in **figure 3**. Additional sports equipment for the lessons such as balls, skipping ropes was offered and organized. Adherence to the PA lessons was assessed by regular classroom teachers.

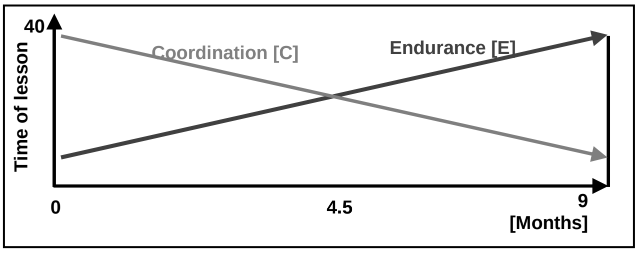


Figure 3: Model for the physical lessons
The physical activity lessons focused on coordination and endurance, but their distribution within one 40 min lesson changed over the period of the study.

Nutrition, media use and sleep lessons: The intervention on healthy balanced nutrition included weekly 45 min nutrition lessons, where the children learned balanced nutrition and healthy nutritional behaviour in a playful way. These lessons were developed and prepared by a dietician. The lessons were based on five messages i.e. “drink water”, “eat fruit and vegetables”, “eat regularly”, “make clever choices”, “turn your screen off when you eat” [42] that were transmitted in the form of a nutrition disk, developed in collaboration with the Swiss Society for Nutrition [45]. Each message was taught during a two-weeks period and was presented in two cycles over the year. Each message was described on a funny card which was taken at home with a task to
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implement the message at home (see below). During two additional weeks, lessons about sleep were implemented.

Infrastructural changes: The infrastructures of the preschool were adapted, in coordination with the building department to ensure the insurance guidelines for prevention of accidents.

Extracurricular activities: This included an additional weekly PA lesson (e.g. clubs). Where there was no offer of inexpensive all-round weekly PA lessons a weekly extracurricular lesson from a new national PA program [46] was offered.

Children and parents:

PA and nutrition home activities: Sixteen PA and five nutrition cards were developed by professional PA teachers/nutritionists in collaboration with Health Promotion Switzerland [43]. The children got every other week a new PA or a nutrition activity card at home. These cards include specific PA tasks to be done at home. Some of these activities focused on a team work, which should promote the integration of other family members. A text on the backside of the card included simple information and practical hints to the parents. A CD with specific music for most PA cards was created to increase pleasure and define the minimal time the activity should be performed.

Events: Toward the end of the intervention, a morning event was organized, where children and parents participated together in a fun program while implementing the main messages of the study.

Parents:

Information evenings: The HP organized two information evenings in each preschool. During the first information evening the HP informed about the study, the intervention, the testing and the informed consent. This information evening was performed also for the CON classes. On the second information evening, the HP presented the nutrition disk, informed about the five nutrition and media use messages and discussed possibilities and barriers of implementation. A third information evening performed by a dietician discussed the possibility of healthy nutrition that is cheap, tasty and can be easily and rapidly prepared.

Information booklet: In a short booklet, parents got informed about: (1) details of the intervention (2) practical hints to increase PA for children and for adults (3) existing PA offers for preschooler in the neighbourhood (4) the material, the children need at home for the home activities (5) the nutrition disc and (6) recommendations for a healthy mid-morning snack.

With the second information event the parents received the nutrition disc (offered in ten languages) and two other booklets about cooking and eating („Gemeinsam Kochen und Essen“, Cleven-Becker-Stiftung, 2008) and about PA in daily life (“Bewegung ist Leben”, Bundesamt für Sport BASPO, 2008), offered in eight languages

Measurements

Measurements at baseline and at the end of the intervention were accomplished during a time period of five weeks (beginning both times in SG). **Table 2** gives an overview about all measurements taken. The measurements were collected in three teams: anthropometry/concentration/memory (tested in the preschool class), motor abilities (tested in the gym) and PA (accelerometry). These teams worked parallel in different classes. With few exceptions the local teams did not change between the two testing periods. The main investigators for SG and VD were trained together to minimize inter-observer variability. Research assistants were blinded to group allocation. If a child was sick, BMI was measured few days later and questionnaires were distributed.

Anthropometry and body composition:

Standing height was determined and body weight was measured using an electronic scale (Seca, Basel, Switzerland; accuracy 0.05 g). Waist (midway between the iliac crest and the lowest border of the rib cage) and hip circumference (at the largest circumference) were measured by a flexible tape. SF thickness was measured in triplicate to the nearest 0.5 mm with Harpenden calipers (HSK-BI, British Indicators, UK) calibrated to exert a pressure of 10 g/cm^2 to the skin. Four sites (triceps, biceps, subscapular and suprailiac) were measured based on standard procedures [47]. The same four investigators took all measurements. Percent body fat was calculated according to the formulas of Slaughter, Deurenberg and Dezenberg [48-50] validated in preschool children [51, 52]. The calculation of % body fat with this method has a prediction error of 3-5 % [48, 49]. The intra- and interobserver correlations in the pilot study (n=21) using Spearman rank correlation analyses were r=0.95 (p<0.001) and r=0.90 (p<0.001), respectively for waist circumference and r=0.98 (p=0.001) and r=0.96 (p=0.001), respectively for the sum of four SF. Bioelectrical impedance was measured by a 4-polar single frequency device (RJL Systems, Model 101A; Detroit, MI, USA). The unit was calibrated prior to each testing day using a 500 ohm resistor provided by the company. Measurements were taken based on standard procedure[53]. If the distance from the proximal to the distal electrode was less than 5 cm in small children, the proximal electrode was located more proximal until the distance of 5 cm was attained. Percent body fat was calculated based on validated formulas [52, 54, 55]. The coefficient of variation between different bioelectrical impedance analysis measurements was less than 1.5 % and for the calculation of fat-free mass it was 5.8 % [52].

Motor abilities:

Shuttle run test: The maximal multistage 20 m shuttle run test (20-MST) was used to assess aerobic fitness [56]. The test measures aerobic capacity by running forth and back for 20 m with an initial running speed of 8.0 km/h and a progressive 0.5 km/h increase of the running speed every minute that is indicated by a sound. The maximal performance was determined when the child was twice in series more than 3 m behind the given time or the child decided itself to stop because of exhaustion. The 20-MST has been found to be reliable (test-retest r=0.73-0.93) [56-58], a valid measure of maximum oxygen consumption as measured by treadmill testing (r=0.69-0.87) [57-61], and sensitive to changes in 6- to 16-year old children [61]. Some formal adoptions were made due to the very young age of the children by marking tracks on the floor to prevent the children from running curves and by an adult running with the children to provide the adequate pace.

Table 2: Overview of the measurements:

Anthropometry and body composition	PA, nutritional intake and behaviour, media use, sleep duration
Height	Accelerometers, questionnaires*
Weight	Food frequency questionnaire*
Waist and hip circumference	
Skinfold thickness (triceps, biceps, subscapular, suprailiacal)	Psychosocial health
	General health of the child and the family*
Bioelectrical impedance (4-Polar)	Health-related quality of life (HRQOL)*
	Signs of Hyperactivity (SDQ)*
Motor ability	
Shuttle run test (aerobic fitness)	Cognition tests
Balance platform (static balance)	Attention (KHV-VK)
Balance beam (dynamic balance)	Spatial working memory ability (IDS)
Obstacle course (combination)	

* evaluated by a total of two questionnaires (one for lifestyle parameters, general and psychosocial health, one food frequency questionnaire)

Balance platform: Static postural control was measured in accordance to a standardized protocol [64] on a balance platform (GKS 1000®, IMM, Mittweida, Germany). The balance platform consisted of four sensors measuring displacements of the center of pressure (COP) in medio-lateral and anterior-posterior direction. Data acquisition was monitored (40 Hz) for 25 sec [64]. A balance-pad (Airex balance Pad, Airex, Aalen-Ebnat, Germany) was put on the balance platform, increasing the difficulty of the test. Postural sway was collected measuring the displacement of the COP. The smallest total length of two trial was used for further analysis. For experimental testing, children were asked to stand barefoot, with a 2 cm distance between both heels and feet placed in a 30° angle on the balance-pad, where coloured foot prints were placed. Hands were placed on the hips. After a test-stand for five seconds and a break while children descended from the force plate, the two trials were collected. The intraobserver test-retest correlation for the total length between the two attempts in the pilot study (n=40) using Spearman rank correlation analyses was r=0.73 ($p<0.0001$).

Balance beam: According to Keogh (1965) balance beams are a suitable tool for testing dynamic balance in children [65]. In pilot testing we observed that balancing backwards was too difficult for children aged 4- to 6-years but balancing forward on a 3 cm wide balance beam was feasible and discriminated between children with high and low motor skills. We therefore included balancing barefoot forward on a 3 m long and 3 cm wide balance beam. The number of successful steps on the beam were counted until the child's foot touched the floor. Children performed three trials. The mean of the best two trials was calculated and used for further analyses. The intra- and interobserver correlation between the two better attempts in a pilot study (n=15) using Spearman rank correlation analyses were r=0.84 ($p<0.01$) and r=0.97 ($p<0.01$), respectively.

Physical activity:

PA was assessed by an accelerometer (MTI/CSA 7164, Actigraph, Shalimar, FL, USA). The accelerometers were constantly worn around the hip over five days at baseline and at the end of the intervention (both summertime) in the INT and in the CON group. The sampling epoch was set at 15 sec. This instrument has been shown to be valid across different activities in 3- to 5-year old children with a Pearson correlation coefficient between VO_2 (ml/kg per min) and Actigraph counts/15 sec of r=0.82 [66].

Questionnaires:

Table 3 gives an overview of the two used questionnaires [67-74]. The reliability of a semi-qualitative food frequency questionnaire was tested in three classes assessing nutritional behaviour and food intake of preschool children of predominantly migrant background (Ebenegger, V. manuscript in preparation). Items were chosen from different food frequency questionnaires [67-69] adapted to the Swiss situation and the age group. This food frequency questionnaire was also filled in for each sibling aged two years or older.

Table 3: Overview of the questionnaires:

General Health Questionnaire	Food frequency questionnaire (adapted from [67-69])
• PA and participation in sports clubs of the child and the family [73] • media use and sleep duration [74] of the child and its siblings • General health of the family members • Parental height and weight • Socioeconomic data (i.e. education, origin, nationality and cultural integration) • health-related quality of life (HRQOL)* [70] • presence of a hyperactive behavior with the Strengths and Difficulties Questionnaire (SDQ)** [71]	• Nutritional behavior (i.e. if and where (i.e. home, day care) the meals were eaten, eating while watching television, eating alone) • Intake of 15 different categories of food during the last 4 weeks (subdivided into nutriments)

* HRQOL was measured by the German version of the PedsQL 4.0TM (Pediatric Quality of Life Inventory) Generic Core Scales (U.S. Copyright Registration No. TXu 856-101) with a parent proxy-report, containing four scales (Physical, Emotional, Social, School) and 23 items. The psychometric properties of the PedsQL 4.0TM justify application in a healthy child population [70]. ** The presence of hyperactive behaviour was evaluated with the Strengths and Difficulties Questionnaire (SDQ) [71]. The parent proxy-form comprised the hyperactivity/inattention scale consisting of five items. Validity has been demonstrated in healthy children and adolescents [72].

Cognition tests:

To measure attention ability, the *Konzentrations-Handlungsverfahren für Vorschulkinder* (KHV-VK) [75] was applied. Test material consists of 44 cards with familiar pictures, which had to be sorted into four different boxes. Sorting time and error quote allowed quantitative and qualitative statements on attention. The test has been validated in a preschool population and age specific norms are available. Test-retest reliability was r=0.88 [75].

Spatial working memory ability was measured by a subtest taken from the Intelligence and Development Scales (IDS) [76]. Thereby geometrical forms had to be memorized and identified. Significant correlations to related measures confirmed construct validity (i.e. HAWIK-IV Working memory scale: r=0.52) and the test-retest reliability was r=0.48 [77, 78].

Evaluation

All evaluation measures were developed as defined in the CONSORT guidelines [79]. We will evaluate the intervention with regard to primary and secondary outcome measures. We will also perform a process evaluation to assess the appreciation the feasibility and the subjective effectiveness of the program by teachers (questionnaires and semi-qualitative interviews) and parents (questionnaires).

Data analysis

Baseline comparability of INT and CON schools will be assessed using descriptive statistics and two sample *t* test for continuous and χ^2 test for categorical variables. If necessary, variables will be logarithmically transformed before analyses. As a primary prevention program, the intervention was designed to target the entire sample. Effects are expected and intended to occur throughout the entire distribution of adiposity and aerobic fitness in the sample – not just around a defined threshold. Thus, for purposes of establishing the efficacy of this intervention, it is most appropriate to compare the full distributions of BMI and aerobic fitness between INT and CON groups. Therefore, to test the primary hypotheses, accounting for the design with classes as the unit of randomization, mixed linear models will be used, with change in BMI and aerobic fitness as the dependent variable, study arm as the factor of interest and age, sex, language region (German vs. French part of Switzerland) and baseline BMI or aerobic fitness, respectively, as covariates. The same analytic approach will also be used for all secondary outcome variables. Potential interactions of intervention with sex or age will be tested for each outcome. Data will be analyzed according to intention to treat.

With an average class size of 18, we assumed that 13 children per class would participate in both shuttle run-tests (due to non-participation, attrition, moving, sickness on the testing day). A total number of 40 classes would then provide enough power to detect a true intervention effect of half an inter-subject standard deviation at the usual significance level of 0.05 with a probability of 0.9, provided that the standard deviation of the random class effect does not exceed 25 % of the inter-subject standard deviation (i.e., corresponding to an intra-class correlation of about 0.06).

The following subgroups will be also investigated: Normal weight and overweight/obese children, children with low baseline fitness, children with migrant background and Swiss children, children of low socioeconomic background.

Discussion

We achieve to develop a concise and appropriate protocol for the development and implementation of a multilevel lifestyle intervention aiming to prevent weight gain and to increase aerobic fitness in a high-risk preschool population with a high percentage of migrant background. We believe that the inclusion of stakeholders such as teachers, parents and school directors from the very beginning, the extended preplanning inlcuding testing and evaluation of the intervention material and the theory-driven multilevel approach will improve the likelihood of a successful intervention.

The purpose of this paper was to outline the design of a multicomponent multilevel school-based multicenter cluster-randomized, lifestyle intervention trial aiming to reduce BMI and to increase aerobic fitness in 4- to 6-year old preschool children in culturally different parts of Switzerland with a high prevalence of migrant children. We aim to offer information and a solid base for a further adaption and larger implementation of prevention programs focusing on preschool children that are adapted to children of low SES and migrant background. Results of the intervention will be available in 2010.

Competing interests

None of the authors has any competing financial interests.

Authors' contributions

JJP, SK and LZ designed the study. JJP was the principal investigator and is guarantor. JJP, SK, IN, FB, VE, AN, TH and PM established the methods and questionnaires. IN, FB, VE and JP were the main coordinators of the study. IN, FB, VE, UM, AN, PM and JJP conducted the study. CS and PM gave statistical and epidemiological support. IN wrote the article under the assistance of JJP and got additional help from SK and PM. JJP obtained the funding, with the assistance of SK and LZ. All authors provided comments on the drafts and have read and approved the final version.

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Publication 2

Relationship of physical activity with motor skills, aerobic fitness and body fat in preschool children: a cross-sectional and longitudinal study (Ballabeina)

Flavia Bürgi, Ursina Meyer, Urs Granacher, Christian Schindler, Pedro Marques-Vidal, Susi Kriemler, Jardena J. Puder

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Research Article

Relationship of physical activity with motor skills, aerobic fitness and body fat in preschool children: a cross-sectional and longitudinal study (Ballabeina)

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Abstract

Background: Adiposity, low aerobic fitness and low levels of activity are all associated with clustered cardiovascular disease risk in children and their high prevalence represents a major public health concern.

Objective: To investigate the relationship of objectively measured physical activity (PA) with motor skills (agility and balance), aerobic fitness and %body fat in young children.

Design: Cross-sectional and longitudinal analyses using mixed linear models. Longitudinal data were adjusted for baseline outcome parameters.

Subjects: 217 healthy preschool children (age 4-6y, 48% boys).

Measurements: PA (accelerometers), agility (obstacle course), dynamic balance (balance beam), aerobic fitness (20m-shuttle-run) and %body fat (bioelectric impedance) at baseline and 9 months later.

Results: PA was positively associated with both motor skills and aerobic fitness at baseline as well as with their longitudinal changes. Specifically, only vigorous, but not total or moderate PA was related to changes in aerobic fitness. Higher PA was associated with less %body fat at baseline, but not with its change. Conversely, baseline motor skills, aerobic fitness or %body fat were not related to changes in PA.

Conclusions: In young children, baseline PA was associated with improvements in motor skills and in aerobic fitness, an important determinant of cardiovascular risk.

Trial Registration: Trial Registration: clinicaltrials.gov NCT00674544

Introduction

Adiposity, low aerobic fitness and low levels of physical activity (PA) are all associated with clustered cardiovascular disease risk in children [1] and their prevalence, especially when combined, represents a major public health concern [2-4]. Well developed motor skills are possible determinants of fitness and PA in adolescents and young adults [5,6]. In children, a new model suggest a reciprocal and developmentally dynamic relationship between motor skill competence and PA, mediated by factors like physical fitness and obesity [7]. As PA is a potentially modifiable lifestyle behaviour, it is of interest to known the nature of the relationship of **PA** with motor skills, aerobic fitness and body fat.

Several studies described that PA is positively, although weakly, related to different **motor skills** in school [8] and preschool children [9,10]. As those studies represent cross-sectional data, it is difficult to draw conclusions about the direction of causality. Therefore, prospective data are needed that may help to establish recommendations for strategies in health promotion, especially in younger children.

Other cross-sectional studies revealed weak to moderate positive associations between PA and **aerobic fitness** in children [11,12]. Additionally, a study in school children showed that the decrease in habitual PA between 1975 and 2005 was accompanied by a decrease in aerobic fitness [13]. Similarly, high levels of PA in school children were associated with a better aerobic fitness 4 years later [14]. However, there is a lack of longitudinal data looking at the influence of PA on aerobic fitness, particularly in preschool children.

The relationship of PA with **body fat** has been studied in several longitudinal designs, but their results are controversial. Indeed many [15-17], but not all [18] studies in prepubertal children could demonstrate a negative association between PA and increases in body fat.

To our knowledge, previous studies have not investigated the strength of the relationship of PA with motor skills, aerobic fitness and body fat together in one single study. Furthermore, there is a need for longitudinal studies in young children. Therefore, we investigated the cross-sectional and longitudinal relationship of objectively measured PA with motor skills, aerobic fitness and %body fat in a large sample of preschool children.

Methods

Study design and participants

We analyzed data from a randomized controlled trial (Ballabeina-Study, clinicaltrials.gov NCT0067454) [19], in which preschool classes from two separate regions in Switzerland were randomly selected. Children were assessed both at baseline (summer 2008) and 9 months later. Children from the 20 classes of the control group, who did not receive any intervention, were used for these analyses. The study was approved by the respective regional ethical committees and written informed consent from the parents or legal representatives was obtained for 312 children. The present analysis focuses on those 217 children with valid data for all PA and physical fitness measures at both time points (69% of the participating children). Children with and without valid data did not differ in baseline values of PA, physical fitness and anthropometry (all *p*=NS).

Table 1: Descriptive of sample data at baseline

number of children	217
age in years (mean, SD)	5.2 (0.6)
sex	
girls	113 (52%)
boys	104 (48%)
weight status (IOTF cut-offs) [1]	
normal (<90th percentile)	194 (90%)
overweight (90th - 97th percentile)	17 (8%)
obese (≥97th percentile)	4 (2%)
parents with migrant background[1]	
none	48 (24%)
one	59 (29%)
both	94 (47%)
parents with low educational level[1]	
none	85 (59%)
one	30 (21%)
both	29 (20%)

[1] data were not available for all children
Definitions: Migrant background: born outside of Switzerland;
Low educational level: at most 9 years of education

Physical activity

PA was measured over 6 consecutive days with an accelerometer (GT1M, Actigraph, Florida, USA), which was programmed to save data in 15-second intervals (epochs). The Actigraph/CSA is the most commonly used motion sensor in children and has a good reproducibility, validity and feasibility [20]. This particular type of PA assessment has been shown to be valid across different activities in 3- to 5-year old children, with a Pearson correlation coefficient of r = .82 between VO_2 (ml/kg per min) und Actigraph counts/epoch [21].

The accelerometers were worn around the hip. To consider data as valid, at least 3 days of recording (2 weekdays and 1 weekend day) [22] with a minimum of 6 h registration per day were needed. The 6-h-validity was highly correlated with 10-h-validity (*N*=502, *r*=0.92, *p*<0.001). Data from monitored days were extrapolated by weighing weekdays and weekends (5:2). Sequences of at least 10 minutes of consecutive zero values were removed and interpreted as “accelerometer not worn” [23].

Total PA, moderate PA (MPA) and vigorous PA (VPA) were choosen as markers of PA. Total PA was expressed as counts per minute (cpm, total counts recorded divided by daily wearing time). MPA and VPA were based on cut-offs published by Pate et al. [21]: 420-841 counts/15s for MPA and ≥842 counts/15s for VPA. Each 15-second-interval over the specific cut-off was summarized in the corresponding intensity level group and data are presented as the amount of 15-second-intervals per day. As differences in daily wearing time between the groups were negligible and non-significant, we did not adjust for this variable (mean wearing time 10.8 h/day).

Physical fitness

Physical fitness in childhood is a powerful marker of health [24] and can be grouped into two broad categories: health-related aspects (aerobic fitness, muscular strength, muscular endurance and flexibility) and skill-related aspects (agility, balance, coordination, power, reaction time and speed) [25]. In the present study, aerobic fitness was chosen because it represents health-related aspects and agility and balance were selected because they represent some aspects of the skill-related physical fitness.

Agility. Agility [26] was assessed by an obstacle course specifically designed for 3-to 6-year old children and described by Vogt and Kunz [27,28]. It includes running 1 m from a marking cone to a transversally positioned bench, jumping over the bench (36 cm high, 28 cm wide), crawling under the bench and running back to the marking cone three times in a row as fast as possible. The test was assessed by the time needed to complete the obstacle course and was measured in seconds. Each child had two attempts and the faster one was used for further data analysis. The interobserver correlation and the test-retest reliability in our pilot study (*n*=14) were *r*=0.99 (*p*<0.01) and *r*=0.82 (*p*<0.01), respectively.

Balance. Dynamic balance was tested by balancing forward barefoot on a balance beam (3 m long and 3 cm wide) [29]. As an outcome measure, the consecutive successful steps on the beam were counted until the child's foot touched the floor. Children could reach a maximum of eight steps. They performed three trials and the mean of the best two trials was calculated and used for further analyses. The interobserver correlation and the test-retest reliability between the two better attempts in our pilot study (n=15) were r=0.97 (p<0.01) and r=0.84 (p<0.01), respectively.

Aerobic fitness. Aerobic fitness was assessed by the multistage 20m-shuttle run test [30]. The test measures aerobic capacity by running back and forth for 20 m with an initial running speed of 8.0 km/h. The progressive 0.5 km/h increase in running speed every minute was indicated by a sound. The maximal performance was determined when the child could no longer follow the pace or the child decided itself to stop because of exhaustion. The test results were expressed as stages (one stage is approximately one minute). The 20m-shuttle run test has been found to be a reliable (test-retest r=0.73-0.93) [30] and valid measure of maximum oxygen consumption as measured by treadmill testing (r=0.69-0.87) [31,32]. Due to the very young age of the children, some formal adaptations of the original test were made by having an adult running with the children until the end of the test to provide adequate pace. In one of our pilot studies testing these adaptations, scores were measured twice for children aged 4- to 6 years (n=20) and test-retest reliability was (r=0.84, p<0.001).

Table 2: Subjects' characteristics at baseline and follow-up

	baseline *n*=217				**9 months follow-up** *n*=217				**longitudinal change** of overall sample (baseline to follow-up)
	girls *n*=113	boys *n*=104	gender differences *p*-value	overall *n*=217	girls *n*=113	boys *n*=104	gender differences *p*-value	overall *n*=217	*p*-value
BMI (kg/m²)	15.7 ± 1.4	15.7 ± 1.4	ns.	15.7 ± 1.4	15.8 ± 1.6	15.8 ± 1.5	ns.	15.8 ± 1.6	0.024
body fat (%)	24.2 ± 3.8	18.5 ± 4.0	<0.001	21.5 ± 4.8	24.0 ± 3.8	18.9 ± 4.2	<0.001	21.5 ± 4.8	0.742
total PA (cpm)	724 ± 169	742 ± 158	ns.	732 ± 164	788 ± 177	876 ± 243	0.009	831 ± 215	<0.001
MPA (no of 15s-epochs)	269 ± 74	293 ± 67	0.002	280 ± 71	296 ± 72	331 ± 74	<0.001	312 ± 75	<0.001
VPA (no of 15s-epochs)	98 ± 45	112 ± 47	0.028	105 ± 46	126 ±53	152 ± 56	0.002	138 ± 56	<0.001
20m-shuttle run (stages)	2.8 ± 1.2	3.3 ± 1.5	ns.	3.0 ± 1.4	4.2 ± 1.4	4.7 ± 1.8	0.011	4.4 ± 1.7	<0.001
obstacle course (s)	19.6 ± 4.1	18.5 ± 4.3	ns.	19.1 ± 4.2	17.0 ± 3.2	15.9 ± 3.0	0.013	16.5 ± 3.1	<0.001
balance beam (steps)	2.4 ± 1.6	2.3 ± 1.8	ns.	2.4 ± 1.7	3.2 ± 2.1	3.0 ± 1.9	ns.	3.1 ± 2.0	<0.001

Abbreviations: BMI, body mass index; PA, physical activity; cpm, counts per minute; MPA, moderate activity (420-841 counts/15 s); VPA, vigorous activity (≥ 842 counts/15 s);
s, seconds. Mixed linear regression: All analyses were adjusted for age, sex and the effects of clustering by preschool class.

Anthropometry

Body height and weight were measured according to standardized procedures 19. The body-mass-index (BMI) was calculated as weight (kg)/height (m)2. Overweight and obesity were classified according to IOTF cut-offs (Cole). As a marker of body fat we used %body fat which was measured by a 4-polar single frequency bioelectric impedance (RJL Systems, Model 101A, Detroit, MI, USA) and calculated according to a validated formula reported by Kriemler et al. 33.

Socio-cultural characteristics

Socio-cultural characteristics (parental migrant status and education) were assessed by questionnaire. Parental migrant status was determined by their country of birth (migrant status equals being born outside of Switzerland) [34] and educational level as the respective highest grade of school completed [35]. A low educational level was defined as no education beyond mandatory school (9 years). A child was defined as migrant with at least one migrant parent and of low educational level with at least one parent with a low education.

Statistical Analysis

All analyses were performed using STATA version 11.0 (Statacorp, College Station, Tx, USA). For descriptive analyses, the results are presented as means ± standard deviations (SD), as all variables were normally distributed. Gender differences at baseline and follow-up, as well as longitudinal changes within one variable were analyzed using a simple mixed linear model with sex as the only fixed factor and preschool class (cluster) as random factor. To assess the cross-sectional and longitudinal relationships between PA and physical fitness or %body fat, we used mixed linear models with physical fitness or %body fat as outcome variable, PA measures (predictor), age and sex as fixed factors and preschool class (cluster) as random factor. To assess longitudinal changes, the models were additionally adjusted for the respective baseline values of the outcome parameters. In a second step, we adjusted cross-sectional and longitudinal analyses for the following confounder variables: parental migrant status and educational level and, for the fitness variables, %body fat. For better understandability and comparability between different measures, the results of mixed linear models were also expressed in the form of partial correlation coefficients. These coefficients were computed by first regressing outcome and predictor of interest against the same covariates and then correlating the resulting residuals. Conversely, the same regression and correlation analyses were performed with PA measures as outcome variables and the measures of physical fitness or %body fat as the predictors. Interactions between sex and the respective predictor variables were tested. Since no significant interactions with sex were found (all $p \geq 0.1$), we did not stratify analyses by sex. Statistical significance was defined by $p < 0.05$.

Table 3a: Cross-sectional and longitudinal relationships between physical activity and agility

	baseline total PA (cpm)				**baseline MPA** (no of 15s-epochs)				**baseline VPA** (no of 15s-epochs)			
obstacle course (s)	β	95% CI	r^a	*p*-value	β	95% CI	r^a	*p*-value	β	95% CI	r^a	*p*-value
baseline	-0.005	-0.008 -0.002	-0.17	0.004	-0.009	-0.017 -0.002	-0.15	0.016	-0.012	-0.024 -0.0005	-0.13	0.041
changes over 9 months	-0.003	-0.005 0.001	-0.19	0.005	-0.008	-0.012 -0.003	-0.23	0.001	-0.010	-0.016 -0.003	-0.19	0.005

Table 3b: Cross-sectional and longitudinal relationships between physical activity and balance

	baseline total PA (cpm)				**baseline MPA** (no of 15s-epochs)				**baseline VPA** (no of 15s-epochs)			
balance beam (steps)	β	95% CI	r^a	*p*-value	β	95% CI	r^a	*p*-value	β	95% CI	r^a	*p*-value
baseline	0.002	0.001 0.003	0.20	0.004	0.005	0.002 0.008	0.22	0.001	0.007	0.002 0.012	0.20	0.003
changes over 9 months	0.002	0.0003 0.0034	0.15	0.020	0.004	0.001 0.008	0.16	0.020	0.007	0.002 0.013	0.17	0.013

Abbreviations: PA, physical activity; cpm, counts per minute; MPA, moderate activity (420-841 counts/15 s); VPA, vigorous activity (≥ 842 counts/15 s); s, seconds; 95%CI, 95% confidence interval; r^a, partial correlation coefficient. Mixed linear regression: All analyses were adjusted for age, sex and the effects of clustering by preschool class. Longitudinal analyses were also adjusted for baseline outcome parameters.

Comment: The extremely low β-coefficients derive from our scale unit of cpm or number of MPA/VPA-epochs.

Results

Subjects characteristics

The baseline characteristics of the 217 children (mean age at baseline: 5.2 ± 0.6 years, 48% boys) are shown in **table 1**. Outcome measures at baseline and at follow-up are shown in **table 2**. At baseline, there were gender differences in %body fat, MPA and VPA and at follow-up additionally in total PA, aerobic fitness and agility (all $p<0.05$). Over the following 9 months, there were longitudinal changes in all variables (all $p<0.001$), except for %body fat.

PA and motor skills

At baseline, sex- and age-adjusted positive associations were found between PA and agility and balance (all $p<0.04$, **table 3a/b**). For example, an increase of 100 counts per minute at baseline was associated with an increase in agility of 0.5 seconds in the cross-sectional analyses. Likewise, baseline PA was significantly associated with change in agility and balance (all $p \leq 0.02$, **table 3a/b**).

Adjusting for sociocultural confounder variables did not alter those associations. However, after additional adjustment for %body fat, the association between baseline PA with baseline agility (r=-0.10 to -0.11, $p \geq 0.14$) as well as with change in balance (r=0.13 to 0.15, $p \geq 0.05$) did not remain significant.

PA and aerobic fitness

At baseline, positive associations were found between PA and aerobic fitness (all $p<0.001$, **table 4**). Baseline VPA, but not baseline total PA or MPA, was associated with a change in aerobic fitness ($p=0.046$, **table 4**). After adjusting for all confounders, the relationships between baseline PA measures with baseline and change in aerobic fitness remained similar or became even more pronounced.

Table 4: Cross-sectional and longitudinal relationships between physical activity and aerobic fitness

	baseline total PA (cpm)				**baseline MPA** (no of 15s-epochs)				**baseline VPA** (no of 15s-epochs)			
20m-shuttle run (stages)	β	95% CI	r^a	*p*-value	β	95% CI	r^a	*p*-value	β	95% CI	ra	p-value
baseline	0.003	0.002 0.004	0.38	0.000	0.005	0.003 0.007	0.30	0.000	0.010	0.007 0.013	0.37	0.000
changes over 9 months	0.0005	-0.0005 0.0014	0.10	0.326	0.002	-0.001 0.003	0.13	0.079	0.003	0.001 0.007	0.17	0.046

Abbreviations: PA, physical activity; cpm, counts per minute; MPA, moderate activity (420-841 counts/15 s); VPA, vigorous activity (≥ 842 counts/15 s); s, seconds; 95%CI, 95% confidence interval; r^a, partial correlation coefficient. Mixed linear regression: All analyses were adjusted for age, sex and the effects of clustering by preschool class. Longitudinal analyses were also adjusted for baseline outcome parameters.

Comment: The extremely low β-coefficients derive from our scale unit of cpm or number of MPA/VPA-epochs.

PA and %body fat

At baseline, total PA, but not MPA or VPA, was negatively associated with %body fat (*p*=0.04, **table 5**). After adjusting for socio-cultural confounders, the association between total PA and %body fat did not remain significant (*r*=-0.11, *p*=0.15). No longitudinal relationship was found between baseline PA and changes in %body fat.

Determinants of PA changes

No relationship could be found between baseline physical fitness or %body fat and changes in PA. Thereby, the following correlations were found: agility r=-0.03 to -0.12, p≥0.14, balance r=0.05 to 0.07, p≥0.14, aerobic fitness r=0.10 to 0.16, p≥0.06 and %body fat r=-0.05 to -0.15, p≥0.35. Only baseline aerobic fitness was weakly associated with changes in MPA (r=0.16, p=0.04), but also this association did not remain significant after adjusting for confounders.

Table 5: Cross-sectional and longitudinal relationships between physical activity and body fat

	baseline total PA (cpm)				**baseline MPA** (no of 15s-epochs)				**baseline VPA** (no of 15s-epochs)			
percent body fat (%)	β	95% CI	r^a	*p*-value	β	95% CI	r^a	*p*-value	β	95% CI	r^a	*p*-value
baseline	-0.003	-0.007 -0.0001	-0.14	0.040	- 0.006	-0.014 0.001	-0.11	0.115	-0.010	-0.022 0.001	-0.12	0.080
changes over 9 months	0.001	-0.001 0.002	0.05	0.482	0.003	-0.001 0.006	0.12	0.110	0.002	-0.003 0.007	0.06	0.447

Abbreviations: PA, physical activity; cpm, counts per minute; MPA, moderate activity (420-841 counts/15 s); VPA, vigorous activity (≥ 842 counts/15 s); s, seconds; 95%CI, 95% confidence interval; r^a, partial correlation coefficient. Mixed linear regression: All analyses were adjusted for age, sex and the effects of clustering by preschool class. Longitudinal analyses were also adjusted for baseline outcome parameters.

Comment: The extremely low β-coefficients derive from our scale unit of cpm or number of MPA/VPA-epochs.

Discussion

Main results

In the studied preschool population, PA was related to agility, balance and aerobic fitness in cross-sectional analyses. Our results also showed , that baseline PA was associated with prospective improvements in all of these fitness measures. Thereby, only VPA was related to changes in aerobic fitness, an important determinant of cardiovascular risk. There was a weak relationship of PA with %body fat. We did not find any evidence for a reverse direction of association: Overall, baseline physical fitness or %body fat were not related to changes in PA. As far as we are aware, this is the first longitudinal study investigating the broader relationships of PA with fatness and with different fitness measures in one single study and thus helps to fill the lack of data in young children.

PA and motor skills

The observed weak to moderate associations between PA and motor skills (i.e. agility and balance) are in concordance with previous cross-sectional results in preschoolers [8-10]. Based on these previous studies, it has been hypothesized that performance level in motor skills may predict PA [8,10]. We could not replicate an impact of motor skills on increases in objectively measured PA in young children, but, in contrast, found that higher baseline PA was associated with beneficial changes in motor skills at follow-up. Our data suggest that the relationship between PA and motor skills is dominated by the impact of PA on motor skills. This would be in accordance with the model of Stodden et al. that assumes that young children's PA might drive their development of motor skill competence [7]. This model suggests that in early childhood the relationship between PA and motor skills is still weak, but strengthens over time [7]. If future studies confirm our results, it appears plausible to argue that in young children, initial high motor skills performance levels per se do not guarantee a more active lifestyle, but that there is a need to continuously promote PA throughout childhood.

PA and aerobic fitness

The investigated moderate relationship between PA and aerobic fitness is consistent with cross-sectional data in school children [11,12,36]. Depending on its intensity, PA may have different effects on physical fitness [24]. That is why several cross-sectional studies reported a stronger relationship between VPA and a higher aerobic fitness level in school children and adolescents [12,24,37-41]. In contrast to those findings, we did not observe a more pronounced association with more intense activities in our cross-sectional analyses. However, our longitudinal findings seem to support the general assumption that vigorous activities are stronger related to aerobic fitness. Thus, we confirmed the association of VPA with changes in aerobic fitness in a longitudinal design and extended it to preschoolers. In older children and adolescents, maintaining high levels of PA was associated with high future fitness [14]. However adolescents who were less active at baseline, but subsequently increased their PA levels over the next four years, never reached the fitness performances of children who were active at baseline [14]. These findings strengthen the benefits of being active from early childhood through adolescence.

PA and %body fat

A recent review regarding the association of PA and adiposity concluded that high levels of PA are probably protective against childhood obesity, but that there is a need for more research on this topic in younger children [17]. We only found a relationship between total PA, but not for MPA or VPA with %body fat at baseline. This is in contrast to previous cross-sectional findings in school children [12,40]. This discrepancy could be explained by differences in the proposed cut-offs for more intense activities [12,21,40]. For instance, Bailey et al. [42] reported that school children engaged in only very short bursts of intense PA and therefore it could be possible, that even 15 s epochs may not be sufficient to assess more intense PA. Moreover, we found no longitudinal relationship between baseline PA and changes in body fat, a finding in agreement with a study that also used objectively measured PA in a similar age group [18], but in contrast to other longitudinal studies [15-17]. As activity patterns in young children are by nature often random, sporadic and unsustained, they may not always result in a reduction of body fat [42]. It is possible that a larger amount of PA, a longer follow up or a higher variance of adiposity in the study population are needed to detect marked changes in body fat. Yet, based on our data, it can be concluded that the same activities that were associated with physical fitness were only weakly or not at all related to %body fat. The same results were obtained when using BMI instead of %body fat (data not shown).

Determinants of PA changes

In the present study, baseline motor skills, aerobic fitness or %body fat were not related to changes in PA except for the relationship between aerobic fitness and MPA. However, the latter relationship did not remain significant after controlling for confounders.

In contrast to our data, a few longitudinal studies in school children and adolescents found that **motor skills** were important determinants of reported PA [5,43]. Our results are more in line with the findings reported by McKenzie et al. [44], who also included younger children and found that baseline motor skills (including agility, balance and coordination) were not related to their reported PA 6 years later. The inconsistencies between previous longitudinal studies could be explained by differences in age, the lack of controlling for baseline values, the lack of objective measures of PA and differences in the selected motors skills and tests. For example, some studies tested locomotion, agility and balance [43,44], while another study, additionally tested object control skills or fine motor development [5]. In the present study, not all relevant motor skills for this age group were tested [45]. Thus, we can not exclude that other motor skills like speed and power could also be related to future PA. However, unless future studies show an impact of motor skills on PA in this age group, we cannot assume that high motor skills performance levels will lead to a high level of PA in young children. Nevertheless, differences between our data in young children and previous longitudinal studies can be reconciled by the model of Stodden et al. that presumes that the relationship between motor skill performance and PA is reciprocal, but that it is also developmentally dynamic [7].

High **aerobic fitness** may have an influence on PA, but more data are needed to clarify its impact. We found a positive relationship between baseline aerobic fitness and changes in MPA in our unadjusted analyses only. To some extent, these results support similar data found in school children, where aerobic performance (measured by a 1 mile run) was a predictor of reported PA 4 years later [43] . Percent body fat was not associated with changes in PA in our study. Only few previous studies have focused on the influence of body fat on changes in PA and have yielded controversial results [46,47]. Overall, the body of evidence measuring the impact of physical fitness and body fat on PA is still slim, particularly if compared to the more abundant data focusing on sociocultural predictors of PA in children.

Strengths and limitations

An important strength of this study is the longitudinal design, which allows some conclusions regarding the dominant direction of the observed relationships despite the short follow-up period. Another strength is the adjustment for baseline outcome parameters in the longitudinal analyses which was lacking in most previous studies. Moreover, the adjustment of all analyses for confounders allowed us to show that the relationship between PA with motor skills was in part confounded by %body fat and the relationship between PA with %body fat by sociocultural characteristics. Further strengths of the study are the comprehensive assessments of objectively measured PA, physical fitness and

%body fat in a young population. Nevertheless, the study has some limitations: only a selection of relevant motor skills was investigated. Another limitation is the use of an indirect measurement of VO_2 to test aerobic fitness. This may have diluted the relationship between PA and aerobic fitness. However, the test had a good reproducibility in our pilot, but it has to be mentioned, that the shuttle run test was not validated against a more direct measure of maximal oxygen consumption in children below the age of six. Nevertheless laboratory tests would not have been feasible in this epidemiological approach. In this age group, it can even be hypothesized that fitness tests conducted in the preschool setting may better reflect performances levels in real-life than assessments in more experimental settings. Furthermore, the breakpoint proposed for MPA in this age group corresponds to VO2-thresholds of 20 ml/kg/min [21]. This in turn corresponds to 3-4 METS, if the Schofield equation is used to calculate basal metabolic rate [48]. It might therefore be, that time in MPA is overestimated. Although our sample size was very similar to previously mentioned longitudinal studies, we cannot exclude that a larger sample size could have enabled us to detect a significant relationship between baseline physical fitness and changes in PA, although the correlation coefficients were clearly smaller than for the reverse relationships.

Conclusions

This study showed that PA correlates with physical fitness including agility, balance and aerobic fitness in young children. Our results indicate that an early and continuous promotion of PA throughout childhood may be essential. But we assume that a larger amount of PA or a longer follow up may be required to possibly induce changes in body fat at this young age. These findings contribute to the current understanding for more evidence-based public health policies in young children.

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Conflict of interest

The authors declare no conflict of interest.

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Publication 3

Socio-cultural determinants of adiposity and physical activity in preschool children: a cross-sectional study (Ballabeina)

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Research Article

Socio-cultural determinants of adiposity and physical activity in preschool children: a cross-sectional study (Ballabeina)

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Abstract

Background: Both individual socio-cultural determinants such as selected parental characteristics (migrant background, low educational level and workload) as well as the regional environment are related to childhood overweight and physical activity (PA). The purpose of the study was to compare the impact of distinct socio-cultural determinants such as the regional environment and selected parental characteristics on adiposity, PA and motor skills in preschool children.

Methods: Forty preschools (N=542 children) of two culturally different urban regions (German and French speaking part of Switzerland) participated in the study (Ballabeina Study). Outcome measures included adiposity (BMI and skinfold thickness), objectively measured inactivity and PA (accelerometers) and agility performance (obstacle course). Parental characteristics (migrant status, educational level and workload) were assessed by questionnaire.

Results: Children from the French speaking areas had higher adiposity, lower levels of total and of more intense PA, were more inactive and less agile than children from the German speaking regions (percent differences for all outcome parameters except for BMI ≥10%; all p≤0.04). Differences in skinfold thickness, inactivity and agility, but not in PA, were also found between children of Swiss and migrant parents, though they were ≤8% (p≤0.02). While paternal workload had no effect, maternal workload and parental education resulted in differences in some PA measures and/or agility performance (percent differences in both: ≤9%, p≤0.008), but not in adiposity or inactivity (p=NS). Regional differences in skinfold thickness, PA, inactivity and agility performance persisted after adjustment for parental socio-cultural characteristics, parental BMI and, where applicable, children's skinfolds (all p≤0.01).

Conclusions: The regional environment, especially the broader social environment, plays a prominent role in determining adiposity, PA and motor skills of young children and should be implicated in the prevention of obesity and promotion of PA in children.

Trial Registration: Trial Registration: clinicaltrials.gov NCT00674544

Background

Childhood overweight and obesity have been increasing dramatically worldwide, even in young children. Despite a possible stabilization, the high prevalence remains a great public health concern [1]. Among several environmental factors, a sedentary lifestyle and a reduction in physical activity (PA) are implicated in this increase in body fatness [2]. Some data indicate that children have become less physically active [3-5]. It has recently been reported that 3- to 5-year old children spend around 80% of their time in activities classified as sedentary or at most light PA [6]. Furthermore, a trend towards a decline in motor performance has already been noticed in young children [7].

Individual socio-cultural determinants such as selected parental characteristics (migrant background, low educational level and high workload) are known risk factors for childhood overweight/obesity and inactivity [8-11]. In addition, there exist also regional variations of overweight and physical inactivity [12,13]. Even within Europe, prevalence in overweight differs among countries, ranging from 5 to 25% [12,13]. However, there is a lack of data on the respective roles of individual and environmental determinants in a well defined setting. With its linguistic and cultural diversity, Switzerland offers the opportunity to study diverse cultural environments within the same country. It can thus serve as a model to examine the impact of the regional environment on adiposity, PA and motor skills in children.

In the present study, we assessed differences in adiposity, objectively measured PA, sedentary behaviour and agility performance in preschool children according to different socio-cultural determinants (parental migrant status, education, and workload) and the regional environment.

Table 1: Subjects' characteristics

	Total *n* = 542	German speaking *n* = 267	French speaking *n* = 275	*p*-Value
Mean age (years)	5.1 ± 0.60	5.1 ± 0.59	5.2 ± 0.62	0.2
Sex: Boys / Girls	264 / 278	131 / 136	133 / 142	0.8
%	49 / 51	49 /51	48 / 52	
Parental migrant status: migrant[1] / non-migrant	391 / 151	176 / 91	215 / 60	< 0.001
%	72 / 28	66 / 34	78 / 22	
Parental education: low[2] / middle, high	179 / 306	68 / 165	111 / 141	< 0.001
%	37 / 63	29 / 71	45 / 55	
Paternal workload: no / part time / full time	17 / 24 / 445	7 / 9 / 216	10 / 15 / 229	0.5
%	3 / 5 / 92	3 / 4 / 93	4 / 6 / 90	
Maternal workload: no / part time / full time	182 / 213 /99	88 / 117 / 28	94 / 96 / 71	< 0.001
%	37 / 43 / 20	38 / 50 / 12	36 / 37 / 27	

[1] at least 1 parent born outside Switzerland
[2] at least 1 parent with no education beyond mandatory school (9 year)
Data are shown as means +/- SD or as percentage

Methods

Study design and participants

All children participated in the Ballabeina-Study, the description of which has been reported previously [14]. Briefly, 40 public preschools with a high migrant prevalence (>40% migrants) were randomly selected in two distinct similar-sized urban areas at the north-eastern and south-western edge of Switzerland, respectively. Of note, the majority of preschools in Switzerland are public. Twenty schools were located in the German speaking region (north-eastern part of Switzerland; city of St.Gallen: 70'000 inhabitants) and 20 in the French speaking region (south-western part of Switzerland; urban surroundings of Lausanne: 50'000 inhabitants). The study was approved by both cantonal ethical committees and the parents or legal representatives of each child provided written informed consent. Of the initial 727 preschool children, informed consent was obtained from 655 (participation rate: 90.1%) and valid PA measures were obtained from 542 children (83% of the participating children). This data set was used for further analyses. Children without valid PA data had higher BMI (16.0 ± SD 1.9 vs. 15.6 ± SD 1.4, p=0.01), but did not differ in body fat, agility performance, migrant status and parental education compared to children with valid PA-data (p>0.20). Of those with valid PA measures, complete questionnaire data were obtained from 485 children.

Adiposity

Body height and weight were measured by standardized procedures [14]. Body mass index (BMI) was calculated by dividing weight by height squared. Prevalence of overweight/obese children was calculated according to IOTF criteria [15]. We used the sum of 4 skinfold thicknesses (triceps, biceps, subscapular and suprailiac) as indicator of body fat. Skinfold thicknesses were measured with a Harpenden caliper using standard procedures [16].

Physical activity and inactivity

PA was measured over 6 consecutive days with an accelerometer (GT1M, Actigraph, Florida, USA), worn around the hip and programmed to save data in 15-second intervals (epochs). The Actigraph/CSA is the most common used motion sensor in children and has a good reproducibility, validity and feasibility [17]. This type of PA assessment has been shown to be valid across different activities in 3- to 5-year old children, with a Pearson correlation coefficient between VO_2 (ml/kg per min) and epochs of r=0.82 [18].

The accelerometers were worn around the hip. To consider data as valid, at least 3 days of recording (2 weekdays and 1 weekend day) [19] with a minimum of 6 h registration per day were needed. The 6-h-validity was highly correlated with 10-h-validity (N=502, r=0.92, p<0.001). Data from monitored days were extrapolated by weighing weekdays and weekends (5:2). Sequences of at least 10 minutes of consecutive zero values were removed and interpreted as "accelerometer not worn" [20].

Total PA, moderate-vigorous physical activity (MVPA) and vigorous physical activity (VPA) were chosen as markers of PA and inactivity as marker of sedentary behaviour. Total PA was expressed as counts per minute (cpm, total counts recorded divided by daily wearing time). MVPA and VPA were based on cut-offs published by Pate et al. [18]: ≥420 counts/15s for MVPA and ≥842 counts/15s for VPA and inactivity was defined as 0-25 counts/15s [21]. Each 15-second-interval over or under the specific cut-off was summarized in the corresponding intensity level group and data are presented as the amount of 15-second-intervals per day. Differences in daily wearing time between the groups were negligible. Therefore, we did not adjust for this variable (mean wearing time 10.8 h/day).

Motor skills

Motor skills were assessed by the time needed to complete an obstacle course. This test was described by Vogt and Kunz [22,23] to test agility among 3- to 6-year old children. It includes running 1 m from a marking cone to a transversally positioned bench, jumping over the bench (36 cm high, 28 cm wide), crawling under the bench and running back to the marking cone three times in a row as fast as possible. Time was measured in seconds. Each child had two attempts and the faster trial was used for further data analysis. The intra- and interobserver correlations in our pilot study (n=14) were r=0.99 (p<0.01) and r=0.82 (p<0.01), respectively.

Table 2: Differences in adiposity, PA and agility performance between the German and French speaking region

	German speaking (mean ± SD) n = 267	**French speaking** (mean ± SD) n = 277	***p*-Value**
BMI (kg/m^2)	15.5 ± 1.5	15.7 ± 1.4	0.04
Skinfold thickness (mm)	25.5 ± 7.8	28.2 ± 8.3	< 0.001
Percentage overweight/obese children (%)	9.0	11.0	0.5
Total PA (counts per minute, cpm)	771 ± 169	684 ± 151	< 0.001
MVPA (number of 15-s-intervals/day)	400 ± 110	361 ± 101	0.001
VPA (number of 15-s-intervals/day)	110 ± 45	95 ± 42	0.006
Time spent playing outdoors (min/day)	110 ± 59	74 ± 47	< 0.001
Inactivity (number of 15-s-intervals/day)	1276 ± 216	1400 ± 253	< 0.001
TV time (min/day)	45 ± 43	67 ± 50	0.001
Obstacle course (s)	18.3 ± 3.3	20.0 ± 5.1	< 0.001

Variables were analyzed using mixed linear or logistic regression models with preschool class as a random effect.
Data are shown as means +/- SD or as percentage.

Socio-cultural determinants

We investigated the respective role of different socio-cultural determinants: the broad regional environment on one side and individual socio-cultural determinants, such as parental migrant status, educational level and workload (parental characteristics) on the other side. The regional socio-cultural environment was defined by language and geographical region (German speaking, north-eastern versus French speaking south-western part of Switzerland) [24]. Both regions have a very similar climate. For information about parental socio-cultural characteristics (migrant status, education and workload), parents filled out a general health questionnaire. Parental migrant status was determined by their country of birth (e.g. born outside of Switzerland) the educational level as the respective highest grade of school completed (5 levels). Low educational level was defined as no education beyond mandatory school (9 years). For analyses, migrant status and low parental education were divided in two categories (at least one parent migrant/with low education – no parent migrant/with low education). Maternal and paternal workloads were divided into three categories: no professional activity, part-time and full-time. Due to school legislation, no information could be obtained about economic (i.e. earning, wages) data.

Time spent playing outdoors (min/day) as an additional measure of PA [25] and television (TV) time (min/day) as an additional measure of sedentary behaviour were also asked to the parents. The questionnaire also asked for ways of commuting to school and barriers to play outdoors such as road traffic, lack of playgrounds or courtyards, danger of crime or simply the lack of interest to play outdoors.

Statistical analyses

All analyses were performed using STATA version 11.0 (Statacorp, College Station, Tx, USA). Differences in the subjects' characteristics between the 2 regions were compared using independent t-tests for continuous variables and Chi square-calculations for categorical variable. Measures of adiposity, PA and agility performance are presented as means ± standard deviations (SD), as all variables were normally distributed. We used mixed linear or logistic regression models with adiposity measures, PA, sedentary behaviour and agility performance as outcome variables; regional environment or parental characteristics, as respective fixed factors and preschool class as random effect. Between-group differences were also expressed in percentages using the healthier behaviour (i.e. higher PA) or lower adiposity measure as a denominator. To test the independent effect of the regional environment (fixed factor), regression models were subsequently adjusted for sex, age, parental migrant status, educational level, workload and BMI & children's skinfolds. Significance was assumed at $p<0.05$.

Table 3: Differences in adiposity, PA and agility performance between children of migrant and non-migrant parents

	Non-migrants (mean ± SD) *n* = 151	**Migrants**[1] (mean ± SD) *n* = 393	***p*-Value**
BMI (kg/m^2)	15.5 ± 1.1	15.7 ± 1.5	0.2
Skinfold thickness(mm)	25.3 ± 5.7	27.4 ± 8.9	0.01
Percentage overweight/obese children (%)	7.0	11.0	0.1
Total PA (counts per minute, cpm)	752 ± 176	717 ± 161	0.2
MVPA (number of 15-s-intervals/day)	379 ± 103	380 ± 109	0.5
VPA (number of 15-s-intervals/day)	104 ± 45	102 ± 44	0.8
Time spent playing outdoor (min/day)	99 ± 58	86 ± 54	0.1
Inactivity (number of 15-s-intervals/day)	1291 ± 229	1357 ± 247	0.02
TV time (min/day)	34 ± 30	65 ± 48	< 0.001
Obstacle course (s)	18.2 ± 3.5	19.5 ± 4.7	0.005

[1]at least one parent born outside Switzerland
Variables were analyzed using mixed linear or logistic regression models with preschool class as a random effect. Data are shown as means +/- SD or as percentage.

Results

Baseline characteristics

Baseline characteristics of the study population are presented in Table 1. Significant regional differences in parental socio-cultural factors were observed (all $p<0.05$). In the French part, more parents were migrants, had a low education or a higher workload (all $p<0.05$). The most important migrant regions were: South-Western Europe 25% (Portugal, Italy, France, Spain), South-Eastern Europe 24% (Balkan area, Turkey), other Europe 25%, Africa 12%, North and South America 8% and Asia 8%.

Differences due to the regional environment

Differences in adiposity, PA measures and agility performance between the children in the German and French speaking part are shown in Table 2. BMI, skinfold thickness and sedentary behaviour (inactivity and TV viewing) were higher and total PA, MVPA, VPA and agility performance were lower in the French speaking compared to the German speaking part (all $p\leq0.04$)). Percent differences in all measures except for BMI were 10% or more.

When considering only children of migrant parents (n=391), regional differences in all outcome parameters were similar to those observed in the total population (all $p<0.05$). This was also true for children of Swiss parents (n=151), except that the differences in BMI (p=0.20), % body fat (p=0.07) and agility performance (p=0.1) were not significant. Finally, mentioned barriers to play outside (road traffic, lack of playgrounds or courtyards, danger of crime or lack of interest to play outdoors) did not differ between both regions (all p=NS).

Differences due to parental characteristics

Migrant status. Compared to children of Swiss parents, children of migrant parents had higher skinfold thickness, were more inactive, spent more time watching TV and were less agile (all $p\leq0.02$, Table 3). Those differences generally ranged from 4-8%, while a stronger difference was found for time watching TV (75%). Conversely, there were no differences in BMI and PA.

Parental educational level. No significant differences were found in adiposity or measured PA according to the parental educational level (low vs. middle/high). However, children of parents with low education were less agile (mean difference: 1.5 s, $p<0.001$) and watched more TV (mean difference: 33 min, $p<0.001$) than children of parents with middle/high educational level. Differences in agility amounted to 8%, but a stronger difference was found for time watching TV (75%). Similar results were obtained when maternal and paternal educational levels were analyzed separately according to 5 educational levels (data not shown).

Parental workload. Nine out of ten (92%) fathers worked fulltime. Paternal workload was not related to differences in adiposity, PA and agility performance of the children. Conversely, compared to children of mothers without professional activity, children of part-time working mothers had higher total PA (mean difference: 45cpm, p=0.006) and spent more time in VPA (mean difference: 10 intervals of 15 s, p=0.02), were more agile (mean difference: -1.2 s, p=0.008) and watched less TV (mean difference: 10 min, p=0.03), while children of full-time working mothers were more inactive (mean difference: 61 intervals of 15 s, p=0.04). Children of working mothers (both part-time and full-time) spent more time in MVPA than children of mothers without professional activity (mean difference: 25 resp. 26 intervals of 15 s, p=0.02 resp. p=0.046). Altogether, these differences amounted to ≤9%, while a large difference was found for time watching TV (20%).

Effect of the regional environment

Effect sizes of differences between the French compared to the German region are presented in Table 4 before and after adjustment. Regional differences in body fat, PA, inactivity and agility performance persisted after adjustment for sex, age, parental socio-cultural characteristics, parental BMI and children's skinfolds. Only differences in BMI did not remain significant (p=0.3). Adjusting only for parental characteristics (either analyzing migrant status, educational level and workload separately or together) did not alter these results (data not shown). On the other hand, only the following differences according to parental characteristics remained significant: higher time spent watching TV (children of migrant and low educational level parents), higher adiposity (children of migrant parents) and a higher total PA and MVPA (children of part-time working mothers compared to children of mothers without professional activity); all p≤0.03. In most circumstances, their effect was attenuated compared to the non-adjusted values (data not shown).

Table 4: Multivariate-adjusted regression model analyzing differences of the French compared to the German speaking region

Outcome variable	**Crude model:** Adjusted for sex & age		**Adjusted Model:** Adjusted for sex, age, parental characteristics and adiposity	
	β-coefficient (95% CI)	*p*-value	β-coefficient (95% CI)	*p*-value
BMI	0.3 (0.02; 0.5)	0.03	0.2 (-0.1; 0.4) [1]	0.3
Skinfolds (mm)	2.7 (1.3; 4.1)	< 0.001	2.1 (0.4; 3.7) [1]	0.01
Total PA (cpm)	-88 (-127; -50)	< 0.001	-99 (-133; -64)	< 0.001
MVPA (15-s-intervals/day)	-52 (-77; -27)	0.001	-52 (-73; -31)	< 0.001
VPA (15-s-intervals/day)	-15 (-26; -5)	0.004	-18 (-29; -7)	0.001
Time spent outdoors (min/day)	-35 (-48; -21)	< 0.001	-30 (-44; -16)	< 0.001
Inactivity (15-s-intervals/day)	125 (85; 165)	< 0.001	134 (85; 182)	< 0.001
TV time (min/day)	22 (10; 34)	< 0.001	16 (4; 28)	0.01
Obstacle course (s)	1.8 (1.0; 2.6)	< 0.001	1.4 (0.6; 2.3)	0.001

[1] adjustment was done without children's skinfolds.
Variables were analyzed using mixed linear regression models with preschool class as a random effect with adjustment for sex and age (crude model) or for sex, age, parental migrant status, educational level, workload and BMI & children's skinfolds (adjusted model).
Results are expressed as β-coefficient (95% CI).

Discussion

Our results strengthen the importance of the regional environment on lifestyle behaviours and obesity in very young children. The main findings of this study are: Within the same country with the same national health policy, preschool children from the French speaking, south-western part of Switzerland had an increase in adiposity, were more sedentary, less physically active and less agile compared to the German speaking, north-eastern part. Those differences were in the range of 10% or more and persisted after adjustment for parental characteristics. On the other side, parental characteristics like migrant status, low educational level or workload had less impact on adiposity and lifestyle behaviour and their impact was attenuated after adjustment for the regional environment.

Children of migrant parents had more body fat, were more sedentary, less active, and less agile than children of Swiss parents. These findings are in agreement with several studies, which reported that children with a migration background had higher BMI and were less active [9,10,26,27]. Maternal workload and low parental educational level resulted in differences in some PA measures and/or in agility performance, but, in contrast to previous studies [9], not in adiposity. Ethnic and genetic factors can contribute to the increase in adiposity in some migrants, while economic reasons, lack of parental time and support and individual socio-cultural attitudes might also explain some of our data [28]. We could hypothesize that the healthy behaviour found in children of part-time working mothers could be a combination of time, motivation and sufficient financial resources. Parental characteristics had a particularly strong influence on the time spent watching TV. Existing differences in parental characteristics between the two regions could theoretically explain the observed differences in the regional environment. However, the impact of the regional environment on adiposity and all lifestyle behaviours except TV viewing was much larger and persisted after adjustment for the above mentioned parental characteristics.

The regional environment represents the broader social, cultural, economic and built environment, within which individual behaviour occurs [29]. Differences in the socio-cultural environment could explain our findings which are also in concordance with the observed North-South gradient in overweight and obesity within Europe [12,13]. In those studies, a particularly high prevalence of overweight/obesity was described among southern European countries [12,13]. This North-South gradient has also been reported within Italy [30]. Moreover, lower levels of overweight and obesity were found among children in countries of Central and Eastern Europe compared to Western Europe [12,13]. Different regional patterns have been observed for reported PA in children across European countries [12,31,32]. According to our results, the German speaking part of Switzerland reflects the trends in the north-eastern countries, whereas the French speaking region reflects those in the south-western (and Latin) European countries. Even within the same country, with almost identical climatic conditions, we could observe this North-South gradient in two urban areas. This could be explained by different prevailing cultural norms, attitudes and beliefs. Indeed, differences in health beliefs have been associated with differences in PA in young adults [32]. Furthermore, similarly to many northern countries, general efforts in health promotion have a stronger tradition in the north-eastern part of Switzerland compared to the south-western counterparts. Within Switzerland, similar differences in PA were also observed in large representative samples of adults, where PA levels, reported by questionnaires, were found to be higher in citizens of the German compared to the French speaking part of Switzerland [24,33]. In addition, reported time spent playing outdoors has been shown to be higher in school-aged children and adolescents of the German compared to the French speaking part of Switzerland [34]. Similarly, substantial differences in “active transportation to school” have been documented between German- and French speaking children that were independent of socio-demographic characteristics and environmental factors like distance to school or bike availability [35]. On the other side, lifestyle behaviours within the French and German part of Switzerland, respectively, are reported to be very similar [24,33,34]. In our sample, the observed regional differences were comparable, if the whole population or the subgroup of non-migrant children were analyzed.

Within the social environment, the social network plays a major role and can even influence adiposity more strongly than first grade relatives [36]. In adolescent girls, the role of peer social network factors is crucial for participating in PA [37]. It is quite possible, that also in younger age not only home support and parental modelling, but also larger social networks play an important role [38].

The built environment has also been associated with PA and adiposity and includes access to recreation facilities, parks, playgrounds and traffic [29]. Our regional differences in the outcome parameters observed within the same country could also be influenced by differences in the built environment. Observed differences in time playing outdoors may reflect potential disparities in the access to playgrounds between the two regions, but might also be influenced by the social environment. In this age group, playing outdoors has been shown to be a good marker of PA [25]. Perceived barriers for children to play outdoors like road traffic, lack of playgrounds or courtyards and danger of crime did not differ between both regions, but the parental perception of barriers might be influenced by socio-cultural factors. Furthermore, ways of commuting and school-based structured PA as important factors of PA did not have a large impact on our results, as the great majority of preschoolers in both areas (90%) walked to school and physical education at school did not differ.

Strengths and novelties of the study include the joint comparison of regional and individual determinants within the same small country taking advantage of two distinct socio-cultural regions of similar size and with a similar climate. Further strengths are the comprehensive assessment of adiposity and objectively measured PA and the inclusion of motor skills in a very young population. Since our investigation is not based on a representative sample, we cannot be certain to draw conclusions for the whole population, although differences in reported PA between the French and German regions in large representative samples of adults and in a population of school-aged children and adolescents confirm our findings [24,33-35]. Another limitation is the cross sectional design of the study that limits the investigation of clear cause-effect relationships.

Conclusions

Differences in the regional and especially the broader social environment have a major impact in determining adiposity, sedentary behaviour, PA and motor skills of young children. Although the magnitude of their influence may depend on the specific lifestyle behaviour, their impact on adiposity, PA and motor skills may even exceed the influence of parental socio-cultural characteristics. Should our data be confirmed in future longitudinal studies, high-risk regions in addition to high-risk groups should be identified for future interventions. Thereby, a priority should be made for community-based programs that influence social norms and priorities, and include the adaption of the environment. Specifically, this could include a sensibilisation for the benefits of a healthy lifestyle behaviour and provision of opportunities for recreational activities and outdoor playing.

Competing interests

None of the authors has any competing financial interests.

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Authors' contributions

JJP and SK and designed the study. JJP was the principal investigator and is guarantor. JJP, SK, FB, IN, VE, UM, UG and PM established the methods and questionnaires. FB, IN, VE and JP were the main coordinators of the study. FB, IN, VE, UM, PM and JJP conducted the study. PM gave statistical and epidemiological support. FB wrote the article under the assistance of JJP and got additional help from SK, UG and PM. JJP obtained the funding, with the assistance of SK. All authors provided comments on the drafts and have read and approved the final version.

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List of abbreviations

BMI = Body Mass Index
PA = physical activity
MVPA = moderate and vigorous physical activity
VPA = vigorous physical activity
cpm = counts per minute
TV = television

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Publication 4

Effect of a multidimensional lifestyle intervention on fitness and adiposity in predominantly migrant preschool children (Ballabeina): a cluster randomised controlled trial

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Research article

Effect of a multidimensional lifestyle intervention on fitness and adiposity in predominantly migrant preschool children (Ballabeina): a cluster randomised controlled trial

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We declare that we have no conflict of interest.

Abstract

Objective: To test the effect of a multidimensional lifestyle intervention on aerobic fitness and adiposity in predominantly migrant preschoolers.

Design: Cluster randomised controlled single blinded trial (Ballabeina Study) over one school year; randomisation was performed after stratification for linguistic region.

Setting: 40 preschool classes in areas with a high migrant population in the German and French speaking regions of Switzerland.

Participants: 652 of the 727 preschool children had informed consent and were present for baseline measures (mean age 5.1 years (SD 0.7), 72% migrants of multicultural origins). No children withdrew, but 29 had moved away.

Intervention: The multidimensional culturally tailored lifestyle intervention included a physical activity programme, lessons on nutrition, media use and sleep, and adaptation of the built environment of the preschool and lasted from August 2008 to June 2009.

Main outcome measures: Primary outcomes were aerobic fitness and BMI. Secondary outcomes included percent body fat, waist circumference, motor agility, balance, physical activity, eating habits, media use, sleep, psychological health, and cognitive abilities.

Results: Compared with controls, children in the intervention group had an increase in aerobic fitness at the end of the intervention (adjusted mean difference: 0.32 stages [95% CI 0.07 to 0.57], p=0.01), but no difference in BMI (-0·07 kg/m2 [95% CI -0.19 to 0.06], p=0.31). Relative to controls, children in the intervention group had beneficial effects in percent body fat (-1.1% [-2.0 to -0.2], p=0.02), waist circumference (-1.0 cm [-1.6 to -0.4], p=0.001), and motor agility (-0.54 sec [-0.90 to -0.17], p=0.004). There were also significant intervention benefits in reported physical activity, media use and eating habits, but not in the remaining outcomes.

Conclusions: A multidimensional intervention increased aerobic fitness and reduced body fat, but not BMI in predominantly migrant preschoolers.

Trial Registration: clinicaltrials.gov Identifier: NCT00674544

Introduction

Adiposity and low aerobic fitness in children are associated with a clustering of cardiovascular risk factors.[1] The high prevalence of childhood obesity[2] and low fitness[3 4] represents a major public health burden. Thereby, children with migrant and/or socially disadvantaged background are disproportionately affected.[5 6] Few prevention programmes exist in these populations and they are generally less effective.[7-9] Therefore, there is a large demand for innovative and effective prevention measures that target this high-risk group to avoid the potential widening of health inequalities.

We had previously performed a physical activity (PA) intervention in elementary schoolchildren that decreased adiposity and increased aerobic fitness.[10] Indeed, most prevention studies have been performed in schoolchildren, but few of them reported successful results.[11 12] Focusing on younger children has the advantage to tackle a period where the basis for a healthy lifestyle is still being established. In addition, the preschool period (four to six years) corresponds to the time of the adiposity rebound which is thought to be critical for obesity development.[13] However, little research has been devoted to preschool children. Further, the combined effects of a health-promoting study on aerobic fitness, different adiposity measures, and diverse lifestyle behaviors have never been assessed appropriately.

Existing trials have focused on PA and/or nutrition, but the determinants of obesity and healthy lifestyle behaviors are multiple and inherently complex and interlinked.[14] Therefore, the Ballabeina study was designed to focus on several potentially modifiable lifestyle behaviors implicated in the development of childhood obesity or low fitness such as PA, nutrition, media use and sleep. The main purpose of this multidimensional cluster randomised controlled trial was to increase aerobic fitness and reduce BMI in predominantly migrant preschool children of multicultural origin.

Methods

Study design, setting and participants

The Ballabeina study is a cluster-randomised controlled trial conducted in 40 randomly selected public preschool classes in areas with a high migrant population from two different sociocultural and linguistic regions in Switzerland. The detailed design of the study protocol has been previously described.15 The study was conducted in the German (city of St. Gallen, canton SG; 70'000 inhabitants) and the French (urban surroundings of Lausanne, canton VD; 50'000 inhabitants) speaking regions of Switzerland during the school year 2008/09. The preschool setting was chosen as all children in Switzerland attend preschool.

Preschool classes were the unit for randomisation and intervention. Eligibility criteria for the preschool classes included a >40% prevalence of migrant children (defined as at least one parent born outside of Switzerland16 17) and no participation in any other prevention project.

Randomisation and blinding

Randomisation of classes (1:1) was performed separately for the German (SG, n=20) and French (VD, n=20) speaking parts. Classes were randomised with the use of opaque envelopes. For practical reasons, and to minimise contamination, preschool classes integrated in the same school building were randomised into the same group. Recruitment took place between November 2007 and January 2008. Selection and randomisation took place between February and March 2008 and were performed by a person from the School Health Services who was not involved in the study.

Teachers, parents, and children were informed that the intervention aimed to promote children's health, but were unaware of the main objectives of the study. Specially trained researchers measured outcomes and were blinded to group allocation. Contact persons and organisers (IN, FB, VE) were unblinded, and therefore not involved in measuring outcomes.

Intervention

The rationale, the pilot studies, focus groups and the intervention methods have been previously described in more detail.[15] The intervention lasted one school year (end of August to mid-June 2009) and was based on the following four lifestyle behaviors: PA, nutrition, media use and sleep. The study was designed to intervene at the individual (children, teachers, and parents) and environmental (school curriculum and built environment of the preschool) level and focused on changes in education, attitudes and behavior, and on providing social support. To be culturally tailored, norms and needs were evaluated in different pilot studies and focus groups, information translated as needed, recommendations kept simple and short using many pictures and a focus was set on practical exercises. Trained health promoters intervened on the level of the teachers (workshops, visits with hands-on training, assistance in the adaptation of the built environment), parents (events in collaboration with the teachers) and children (PA lessons).

Children

Children participated in a PA programme consisting of four 45 minute sessions of PA per week. The PA lessons aimed to increase aerobic fitness and coordination skills; they were designed to be playful and organised into themes (e.g. "Clown, Spiderman"). The lessons took place in or around the preschool classroom and once a week in the gym. Health promoters taught one PA lesson/week which was reduced to twice a month after four months. The remaining lessons were provided by the regular preschool teacher. Additionally, there were 22 lessons on healthy nutrition, media use, and sleep. Positive and culturally-independent nutritional messages were based on the five recommendations of the Swiss Society of Nutrition ("drink water", "eat fruit and vegetables", "eat regularly", "make clever choices", "turn your screen off when you eat").[18] In addition, healthy snacks during recess and healthy treats for anniversaries were promoted. In May 2009, a Ballabeina event was organised with games implementing the main messages of the intervention. Stickers that were pasted on a poster in the classroom illustrated the advancement of the programme. Regardless of consent, participation in the intervention was mandatory for all children. Additional information about the intervention material is provided elsewhere.[18 19]

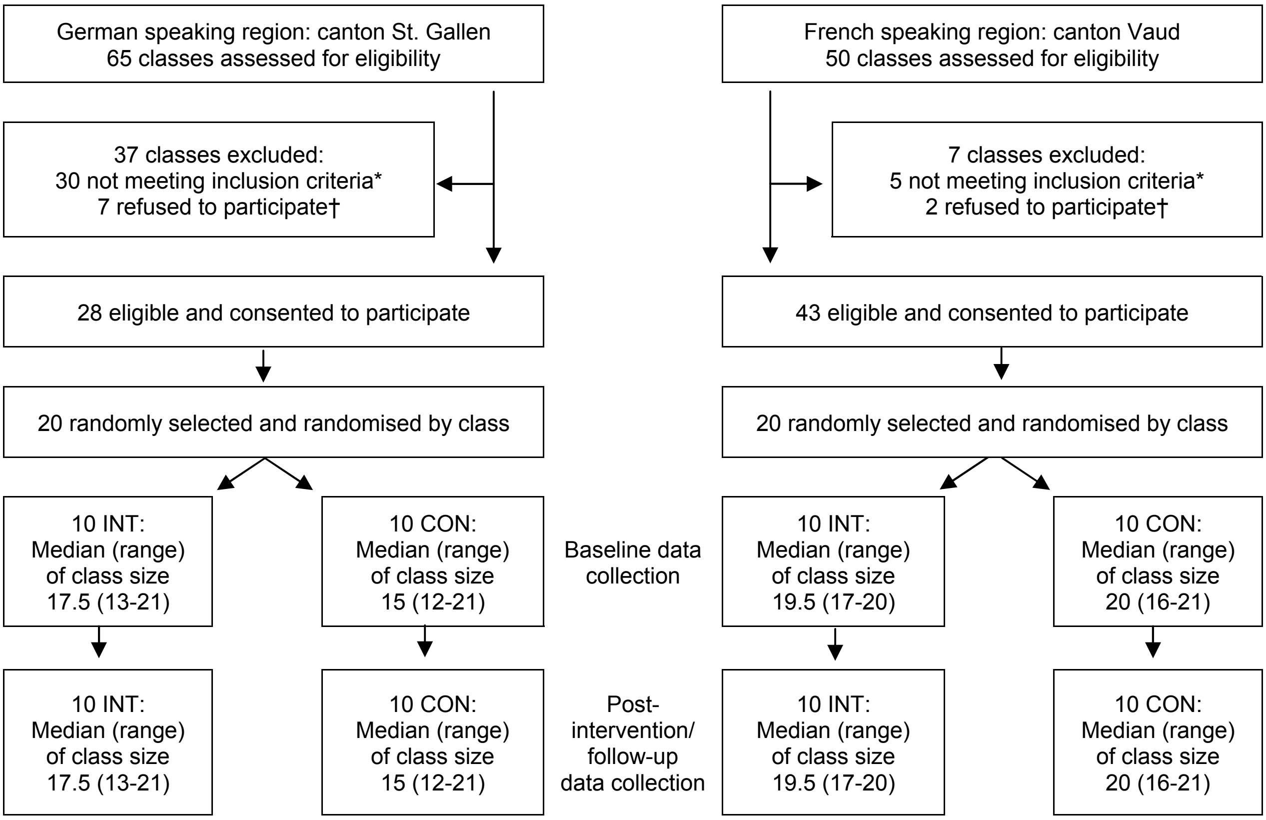


Figure 1: Trial profile of clusters
INT=Intervention classes, CON=Control classes
*Inclusion criteria included a >40% prevalence of migrant children and no participation in any other prevention project.
†Reasons for refusals were lack of interest or time (of the director or the teacher) or health problems of the teacher.

Teachers

Teachers participated in two workshops to learn about the content and the practical aspects of the intervention and in one informal meeting to exchange their experiences. Teachers received the prepared intervention lessons several weeks in advance.

Parents

Parents participated in three interactive information and discussion evenings about promotion of PA, healthy food, limitation of TV use and importance of sufficient sleep. Further support was provided by brochures, funny cards, worksheets, and PA exercises that children brought home. Information leaflets were provided in 10 different languages and native speakers of the main foreign languages were available to answer questions. Participation of children in extracurricular activities was also encouraged, but not verified.

Environmental factors

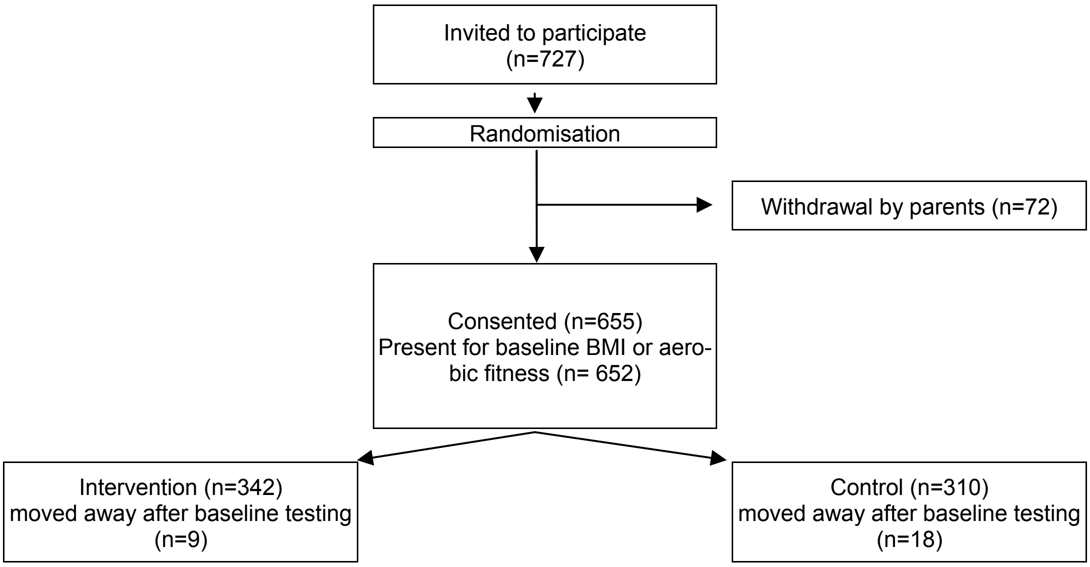
Besides curricular changes, the built environment of the preschool was adapted to promote PA. Thereby, fixed and mobile equipment such as climbing walls, hammocks, balls, cords, or stilts were installed or provided in and around classrooms, including a “movement corner”.

Control group

The control group did not receive any intervention and continued their regular school curriculum which included one 45 min PA lesson per week in the gym; for the French part, one additional 45 min rhythmic lesson per week was provided corresponding to their regular curriculum. Parents of the control group participated in one information and discussion evening. No financial incentives were provided for either intervention of control group.

Objectives and outcomes

We tested the efficacy of the intervention by comparing participants allocated to intervention group with those in the control group at the end of the intervention.[15] Measurements were performed before (August 2008) and at the end of the intervention (June 2009). All primary and secondary outcomes were measured less than two weeks apart and are reported at the individual child level. Physical fitness outcomes were assessed in the gym and adiposity outcomes and cognitive abilities in a separate room close to the classroom. All outcomes were measured by specially trained researchers and the tests in the preschool were supervised by a medical doctor. Additional details on the pre-specified outcomes and pilot studies evaluating the feasibility and test-retest validity of the measures in this population have been previously reported.15



Baseline	Follow-up	Both	**Primary outcomes**	Baseline	Follow-up	Both
342	336	335	BMI*	307	296	291
323	319	302	Aerobic fitness	293	287	269
			Secondary outcomes			
322	327	309	Sum of 4 skinfolds	293	279	263
314	327	301	Percent body fat†	288	278	259
327	329	315	Waist circumference	300	287	277
287	264	236	Physical activity‡	255	220	185
322	326	309	Cognitive abilities§	294	280	264
318	300	286	General health questionnaire║¶	277	265	245
235	222	180	Eating habits**¶	192	198	141

Figure 2: Trial profile of participants.
*BMI at follow-up was also measured in four control and one intervention child that had moved away. †Bioelectrical impedance analysis. ‡Measured by accelerometry. §Attention and spatial working memory. ║Reported PA, sleep duration and media use. ¶Assessed by parental questionnaires. **Completion of all questions related to the five messages of the Swiss Society of Nutrition (used to calculate a sum score). One child with cerebral palsy was excluded from fitness testing.

Primary outcomes included BMI and aerobic fitness. Body height and weight were measured by standardised procedures.15 Aerobic fitness was assessed by the 20 m shuttle run test, where children run back and forth for 20 m with an initial running speed of 8.0 km/h and a progressive 0.5 km/h increase of the running speed every minute.20 Results were expressed as stages, one stage corresponding to the running time of one minute. 8-10 children took the test at one time and each child had a researcher assigned who was checking adequate test procedures. In an unpublished pilot study in this population, test-retest reliability was r=0·84 (n=20, p<0·001).

Secondary outcomes included additional adiposity and fitness measures.15 Overweight was defined according to cut-offs of the International Obesity Task Force (IOTF).21 Bioelectrical impedance analysis was performed using a 4-polar single frequency device (RJL Systems, Model 101A; Detroit, MI, USA) and percent body fat calculated based on a validated formula for children in this age group.22 Sum of four skinfolds (triceps, biceps, subscapular and suprailiac) was measured triplicate to the nearest 0.5 mm with Harpenden calipers (HSK-BI, British Indicators, UK).23 Waist circumference was measured with a flexible tape in midway between the iliac crest and the lowest border of the rib cage. Motor agility (obstacle course) and dynamic balance (balance beam) were tested individually within groups of three to four children. The obstacle course includes the time needed for running 1 m from a marking cone to a transversally positioned bench, jumping over the bench (36 cm high, 28 cm wide), crawling back under this bench, and running back to the marking cone three times in a row as fast as possible.24 25 Dynamic balance included the number of successful steps while balancing barefoot forward on a 3 m long and 3 cm wide balance beam.26 Static balance was determined on a balance platform (GKS 1000®, IMM, Mittweida, Germany) by measuring the displacement (in mm) of the center of pressure in a two-dimensional system27.

Secondary outcomes also included PA measured by accelerometry (MTI/CSA 7164, Actigraph, Shlimar, FL, USA) and reported PA, eating habits, media use, sleep duration, quality of life and cognitive abilities (attention and spatial working memory).15 Accelerometers were consistently worn around the hip over five days at baseline and at the end of the intervention (both summertime) using a sampling epoch of 15 sec/seconds. Eating habits were assessed by the parents with a semi-qualitative food frequency questionnaire.16 28 Healthy eating habits were defined according to the five recommendations of the Swiss Society of Nutrition.16 18 Each recommendation further included two subtopics. For example, for the first recommendation, one topic was the encouragement of water drinking and the second topic the reduction of sweetened drinks. For each topic, we built quartiles of responses, as the values of the respective topics had different codings. Thereby, binary variables were created (coding one for the healthiest quartile vs. zero for the others). The binary variables were further summed up to create a general healthy eating score. “Healthy eaters” thus corresponded to the highest quartile of their recommendations. As numbers with the same values were put into the same category, the number of “healthy eaters” does not exactly correspond to 25%. Other lifestyle characteristics like reported PA29, media use (TV viewing and video games playing), sleep duration,30 health related quality of life (PedsQL 4.0),31 and sociocultural characteristics were assessed by a general health questionnaire that was filled out by the parents. “Active children” were defined as those who answered to be “more” or “much more” active than their peers of the same sex and age.29 Parental migrant status was determined by their country of birth16 17 and the educational level as the highest grade of school completed (five levels). Parental low educational level was defined as education (mandatory school years) of at most 9 years. For descriptive analyses, migrant status and low parental education were divided into three categories (no parent migrant/with low education, one parent migrant/with low education, both parent migrant/with low education). Children were also categorised into two groups according to the language most frequently spoken at home (native language): French/German vs. foreign language. Due to school legislation, no information could be obtained about economic data (i.e. earning, wages). To test attention, children had to sort 40 cards with familiar pictures into four different boxes32 and sorting time (quantitative dimension) and number of correct cards (qualitative dimension) were assessed. To test spatial working memory, an increasing number of geometrical forms which became more and more complex had to be memorised and then recognised from a new set of figures including colors as distractors.33 Process evaluation of the implementation in the preschool was performed by the health promoters and at home through parental questionnaires.

Statistical methods

All analyses were performed using STATA version 11.0 (Statacorp, College Station, Tx, USA). With an average class size of 18, we assumed that, on average, 13 children per class would participate in both shuttle run tests (due to non-participation, attrition, moving, sickness on the testing day). We calculated that a total number of 40 classes would provide 90% power for detecting a true intervention effect of half an inter-subject standard deviation at the significance level of 0.05, provided that the standard deviation of the random class effect does not exceed 25% of the inter-subject standard deviation (i.e., corresponding to an intra-class correlation of around 0.06). We hypothesised a corresponding effect size for change in BMI and shuttle run performance.

Analyses were performed on an intention to treat basis, using individual children data but adjusting for clustering of outcomes within school classes. Data are described by mean ±SD or percentages. Intervention effects were estimated using mixed linear and logistic regression models, adjusting for baseline outcomes, age, sex, sociocultural and linguistic region (German vs. French part of Switzerland) as covariates. Results of logistic regression analyses are presented as odds ratios with 95% confidence intervals. Potential modifications of intervention effects by sex or age were tested and were all found to be non-significant. No p-value adjustment for parallel comparisons was made because the focus was on effect estimation and there is considerable correlation between the outcome and the predictor variables considered.

Table 1: Baseline characteristics of children according to experimental group

	Total	Intervention	Control
Number of children	652	343	312
Girls (%)	50	48.8	51.2
Age, yr (mean, SD)	5.2 (0.6)	5.2 (0.6)	5.2 (0.6)
French versus German part of Switzerland (%)	51.2	51.5	51.0
Parental low educational level (%)*			
None of the parents	61.9	64.6	58.9
One parent	21.3	21.5	21.1
Both parents	16.8	13.9	20
Speaking mainly foreign language at home (%)†	39.5	37.5	41.8
Parental migrant status (%)‡			
None of the parents	27.8	31.0	24.1
One parent	24.5	22.3	27
Both parents	47.8	46.8	48.9
Most frequent migrant regions (%)§			
Former Yugoslavia	24.2	27.9	20.1
Portugal	17	19	14.9
Rest of Europe‖	31	26.3	36.2
Africa	12.1	12.1	12.1
Rest of the World¶	15.7	14.7	16.7

Data were provided by parental questionnaires. *At most 9 years of education. †Any other language than German or French. ‡Born outside of Switzerland. §According to country of birth of the father. Analogous numbers were obtained for the country of birth of the mother. ‖Predominantly Mediterranean and Eastern Europe. ¶Predominantly Asia, Middle East and South America.

Results

Participant flow

Figures 1 and 2 show the flow charts of the trial profile. A total of 40 preschools (727 children) entered the study and were randomly assigned to group (20 interventions, 20 controls) after stratification for sociocultural and linguistic region. Informed consent was obtained from 655 children (participation rate: 90%), and 652 were examined at baseline. A sample of 342 children received the intervention. None of the 40 preschools left the study and 9 children of the control and 18 of the intervention group had moved away by the end of the year.

Baseline data

Children's baseline characteristics are presented in table 1. Of the participating children, 72% had at least one parent and 48% had two parents born outside of Switzerland. We noted no differences in baseline characteristics and outcome variables between the intervention and control group (all p≥0.2).

Outcomes

Data on outcomes are presented in tables 2 and 3. There was a significant higher increase in aerobic fitness in the intervention compared to the control group. Thereby, the adjusted mean difference versus the control group corresponded to 11% of the mean baseline values. Although no group difference in BMI at follow-up was found (table 2), children in the intervention group showed reductions in percent body fat and the sum of four skinfolds and lower increases in waist circumference than control children, with intervention effects being in the order of 5%, 10% and 2% of the respective mean baseline values. They also showed a more pronounced improvement in motor agility (time to perform an obstacle course), but not in static or dynamic balance. There were also significant beneficial intervention effects on reported PA, eating habits and media use. There was no intervention effect for the prevalence of overweight, measured PA, sleep duration, cognitive abilities and quality of life (table 3).

Process Evaluation

A total of 20 (out of 20) evaluation feedbacks of teachers and 297 (out of 342) of parents in the intervention group were obtained over the course of the study. Most of the teachers (95%) attended both workshops and the informal meeting. The majority of PA and nutrition lessons were implemented as planned (95±6% for PA and 88±14% for nutritional lessons). In 85% of the classes, the built environment in or around the preschool was adapted. 85% of parents came to at least one of the three information evenings and over 90% of parents reported having seen the PA and nutrition cards with the home exercises. According to parental report 75 and 80% of the children had done the nutrition and the PA exercises on the cards or worksheets at home and 89 and 92% had liked the respective cards.

Table 2: Adiposity and physical fitness outcomes. Baseline and postintervention values are unadjusted means (SD) unless stated otherwise.

	Baseline		Postintervention		Adjusted difference at follow-up		
	Intervention	Control	Intervention	Control	Coefficients or Odds Ratio (95% CI)*	p value	ICC
Physical fitness							
Aerobic fitness (shuttle run, stages)	2.9 (1.3)	2.9 (1.4)	4.6 (1.7)	4.3 (1.7)	0.32 (0.07 to 0.57)	0.01	0.07
Agility (obstacle course, seconds)	19.4 (4.6)	19.3 (4.4)	16.2 (2.8)	16.7 (3.2)	-0.54 (-0.90 to -0.17)	0.004	<0.01
Dynamic balance (balance beam , steps)	2.4 (1.6)	2.3 (1.7)	3.1 (2.2)	2.9 (2.0)	0.2 (-0.21 to 0.60)	0.35	0.05
Static balance (balance platform, total length, mm)	941 (925)	953 (226)	875 (137)	857 (128)	19.4 (-9.1 to 48.0)	0.18	0.10
Adiposity							
BMI (kg/m^2)	15.6 (1.4)	15.8 (1.6)	15.7 (1.5)	15.8 (1.7)	-0.07 (-0.19 to 0.06)	0.31	0.05
Overweight (BMI ≥90th percentile, %)†‡	10.5	13.0	11.0	14.9	0.65 (0.32 to 1.32)	0.23	<0.01
Percent body fat§	23.7 (6.3)	23.6 (6.8)	23.2 (6.2)	24.1 (6.7)	-1.1 (-2.02 to -0.20)	0.02	0.18
Sum of four skinfolds (mm)	27.3 (8.1)	26.6 (9.2)	25.7 (7.5)	28.4 (11.1)	-2.78 (-4.35 to -1.2)	0.001	0.28
Waist circumference (cm)	52.8 (4.2)	52.8 (4.3)	53.3 (4.1)	54.3 (4.9)	-1.0 (-1.6 to -0.42)	0.001	0.12

ICC=intercluster correlation. CI=confidence interval.
*Change estimates and 95% CIs are the differences between intervention and control group with preschool class as the unit of randomisation and after adjustment by mixed linear or logistic models for the baseline value, age, sex, and language region. †In case of logistic regressions, data are presented as OR (95% CI). ‡Cut-offs of the International Obesity Task Force (IOTF). §Bioelectrical impedance analysis. Samples sizes for each time point (baseline, postintervention and both) are provided in Figure 2.

Adverse events

No injuries or other adverse events have occurred during PA lessons in the intervention classes.

Discussion

Main findings

We employed a multidimensional school-based intervention in predominantly migrant preschoolers in two sociocultural and linguistic different regions in Switzerland. The intervention included a physical activity programme, lessons on nutrition, media use and sleep, and adaptation of the built environment of the preschool. Using approaches designed to target a multicultural population, we observed improvements in aerobic fitness, but no changes in BMI. The intervention also lead to beneficial effects in percent body fat, the sum of four skinfolds, waist circumference, and motor agility. Respective intervention effect sizes of the mean baseline values were 11% for aerobic fitness and 5-10% for body fat. Fitness and body fat are both important health determinants. Their observed improvements point to a combined effect of several potentially modifiable determinants, especially as reported PA, eating habits, and media use showed beneficial changes.

Strengths and limitations

A novelty of the current study is the focus on young migrant children of multicultural origins in Europe, a population at high risk for obesity development.6 Further strengths are the multidimensional approach, the main focus on adiposity and on fitness, the comprehensive assessment, the high participation rate and the rigorous implementation. The inclusion of sleep as part of a lifestyle intervention represents an innovative concept. According to age, sleep durations of 10-10.5 hours per night have been suggested to protect against obesity.34 35 Sleep duration was not influenced by this intervention. However, sleep at baseline might have been sufficient for the large majority of preschoolers, as only 5% slept less than 10 hours per night. Based on our results, future intervention should consider to specifically focus on these high-risk children. The effect of lifestyle on psychological health and cognitive abilities in young children has been previously debated, but not investigated in a randomised design. We therefore included the assessment of those parameters in our school-based intervention. Neither of both measures improved which raises questions regarding their direct link or the need for other approaches. For example, in order to achieve significant neurocognitive benefits, the PA intervention may need to be more intense, or contain more tasks that specifically demand both physical and cognitive resources.

Table 3: Outcomes in lifestyle characteristics, cognitive ability, and quality of life. Baseline and postintervention values are unadjusted means (SD) unless stated otherwise.

	Baseline		Postintervention		Adjusted difference at follow-up		
	Intervention	Control	Intervention	Control	Coefficients or Odds Ratio (95% CI)*	p value	ICC
Lifestyle characteristics							
Total physical activity (cpm)	724 (166)	729 (165)	817 (186)	820 (215)	-12.3 (-51.5 to 26.9)	0.54	0.05
Active children (%)†‡	44.8%	49.0%	53.1%	43.7%	1.7 (1.1 to 2.6)	0.01	<0.01
Healthy eaters (%)†§	26.4%	21.4%	24.3%	12.4%	1.9 (1.02 to 3.6)	0.04	<0.01
Media use (TV & computer, min/d)	65.6 (60.0)	69.1 (63.1)	64.9 (53.0)	81.7 (74.5)	-13.4 (-25.0 to -1.7)	0.03	0.06
Sleep duration (hrs/d)	10.9 (0.6)	10.9 (0.6)	10.9 (0.6)	10.8 (0.6)	0.002 (-0.09 to 0.1)	0.97	0.03
Cognitive abilities and quality of life							
Attention (KHV-VK, duration in min)	5.9 (1.9)	5.9 (1.6)	5.5 (1.5)	5.6 (1.6)	-4.0 (-27.0 to 19.1)	0.98	0.07
Attention (KHV-VK, correct cards)	29.2 (10.4)	28.5 (11.0)	34.8 (5.8)	34.7 (5.6)	0.05 (-0.89 to 0.99)	0.87	0.03
Spatial working memory (IDS)	3.7 (2.0)	3.6 (2.0)	4.8 (1.7)	4.6 (1.7)	0.11 (-0.31 to 0.54)	0.58	0.03
Quality of life (PedsQL, total score)	82.5 (11.0)	82.1 (10.8)	81.5 (11.6)	80.3 (10.4)	1 (-0.57 to 3.1)	0.17	0.02

ICC=intercluster correlation. CI=confidence interval. Cpm=count per minute. KHV-VK=Konzentrations-Handlungsverfahren für Vorschulkinder [Concentration test for preschoolers]. IDS=Intelligence and Development Scales. PedsQL=Pediatric Quality of Life Inventory.
*Change estimates and 95% CIs are the differences between intervention and control group with preschool class as the unit of randomisation and after adjustment by mixed linear or logistic models for the baseline value, age, sex, and language region. †In case of logistic regressions, data are presented as OR (95% CI). ‡Reported by parents to be more active than other children of the same age and sex (Lipid Research Questionnaire). §Correspond to the healthiest quartile of the dietary recommendations of the Swiss Society of Nutrition (Food frequency questionnaire). Samples sizes for each time point (baseline, postintervention and both) are provided in Figure 2.

A limitation of this study is the use of an indirect measurement of VO2 to test aerobic fitness. However, the shuttle run test had a good reproducibility in our pilot trial and laboratory tests would not have been feasible in this epidemiological study. We opted for BMI as our primary outcome in view of a possible implementation strategy including simple and cost-effective measurement tools. However, BMI did not change. A more intense intervention within the preschool setting outside of a research project would not be feasible, but possibly a more extensive involvement of parents, the community and policies.36 On the other side, given the low overweight prevalence at baseline, one could challenge the need to lower BMI. In addition, more specific measurements of body fat may be necessary to measure the effect of a PA intervention in a general non-obese population37 which is consistent with our own results regarding central and total body fat. We found no intervention effect on measured PA. Despite this finding, increases in PA throughout the year are likely to have occurred in view of the improvements in aerobic fitness and motor agility which were manifest in the absence of any BMI-changes. Furthermore, the lack of effect on measured PA might be in part explained by the large intraindividual variability of PA,38 its low measurement precision regarding the extensive use of “gliding activities” on bikes, scooters or roller skates,39 and the fact that the follow-up measurements had to take place at the end of the school year, when the intervention was diluted by other end-of-the year events. Of particular note is that 8 of the 20 control classes indeed had their sports week during their follow-up PA assessment. Another limitation is that the study lacks a long-term assessment of the observed effects. Ideally, a further continuation of this programme into advancing school years should be pursued and its long-term effects evaluated.

Comparison to other studies

Previous trials had demonstrated no or very limited success when intervening in **migrant** or socially disadvantaged children.[7 8 40] In the current study, the many in-school activities and their mandatory nature and the cultural adaptations most likely played a major role for achieving beneficial effects.[41]

In preschoolers, there exist eight RCTs aiming to reduce either **BMI,[9 34 42-47] and/or body fat[42 46 47]**. Of those, one focused on television viewing,[47] the others on physical activity with our without a nutritional intervention, but none was multidimensional. Overall, two studies, combining PA with nutritional interventions, demonstrated beneficial effects.[42 43] One was a small, very intense PA intervention (270 min/week) over 14 weeks.[42] The other, performed in a population with a high baseline prevalence of overweight of over 30%, was less intensive, but included parents with the help of weekly newsletters and homework assignments that were linked to financial incentives.[43] PA in our intervention was rather intense, amounted to 180 min/week and was complemented by home exercises. As addressed in previous studies,[48] a high intensity and parental inclusion may be two important factors to achieve an effect on adiposity in this age group and a more multidimensional approach might be favorable. Two previous RCTs in preschoolers have assessed effects on **aerobic fitness**, but both lack methodological quality using either a 600 m run or a 10 m shuttle run test.[40 42] Similarly to our results, the only other preschool study that used accelerometers, did not find an intervention effect on **PA**.[34]

Implications and generalisability

Aerobic fitness predicts reduced morbidity and mortality in adults49-51 and is associated with a more beneficial cardiovascular risk profile in children.5210 52 As aerobic fitness in children predicts future PA53 it may help to sustain achieved intervention effects. Therefore, and in view of a substantial decrease in children's fitness of 10% over the last 20 years,3 4 the improvements in aerobic fitness in favor of the intervention group are most relevant.

The spread of non-communicable diseases presents a global crisis and affects particularly individuals who are poor which raises already existing inequalities.54 As response to this crisis, a strong focus on primary prevention has been defined as a Public Health priority, encouraging interventions in young children.54 The preschool age is thought to be a critical time for the development of overweight and obesity.13 This was also evident in our study in which the prevalence of overweight, particularly of the control group, started to increase at the end of the study period. The study took place in two sociocultural and linguistic different parts of Switzerland which reflect the broader situation in Europe including more "northern and southern" cultural regions. This and the multicultural origins of the migrant populations suggest the intervention to be more universally applicable within Europe. Based on the few successful preschool interventions,42 43 additional approaches to enhance parental collaboration such as combining school-based interventions with interventions in the health setting and community actions and complementing such programmes with wider environmental and policy intervention should be further evaluated in future studies.

In conclusion, our approaches to target a multicultural population of preschoolers did not change BMI, but resulted in improvements in aerobic fitness and body fat, both important health determinants. Currently, some of the Cantonal Health promotion programmes in Switzerland are implementing several modules of the Ballabeina intervention. Further dissemination of this programme could contribute to reduce some aspects of the burden of chronic diseases and of the health inequalities that have risen as a consequence of social inequities.

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What is already known on this subject:

Obesity and low fitness are disproportionally prevalent in migrant children.
Prevention programmes in this particular multicultural population are scarce, mostly ineffective and even nonexistent in preschoolers.
As obesity is caused by various lifestyle behaviors, there is a need to evaluate multidimensional interventions.

What this study adds:

A multidimensional culturally tailored lifestyle intervention programme improved fitness and body fat in predominantly migrant children.
The preschool age is a critical period to start prevention studies.

Contributors: JJP and SK designed the study. JJP was the principal investigator and is guarantor. JJP, SK, LZ, IN, FB, VE, AN, CS, and PM established the methods and questionnaires. IN, FB, VE and JP were the main coordinators of the study. IN, FB, VE, LZ, AN, PM and JJP conducted the study. CS and PM gave statistical and epidemiological support. JJP wrote the article with the support of SK, PM, FB and IN. JJP obtained the funding, with the assistance of SK and LZ. All authors provided comments on the drafts and have read and approved the final version.
All authors, internal and external, had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis.

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Competing interests: All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare that PMV, AN, CS, VE, FB, IN, LZ, SK, JJP have no relationships with any company that might have an interest in the submitted work in the previous 3 years; their spouses, partners, or children have no financial relationships that may be relevant to the submitted work; and PMV, AN, CS, VE, FB, IN, LZ, SK, JJP have no non-financial interests that may be relevant to the submitted work.

Ethical approval: The study was approved by both ethical committees of the cantons involved in the study (SG and VD) and written informed consent was given by a parent or legal representative of each child.
Data sharing: No additional data available.

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Publication 5

Effect of a lifestyle intervention on adiposity and fitness in socially disadvantaged subgroups of preschoolers: a cluster-randomized trial (Ballabeina)

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Preventive Medicine, submitted

Research Article

Effect of a lifestyle intervention on adiposity and fitness in socially disadvantaged subgroups of preschoolers: a cluster-randomized trial (Ballabeina)

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Abstract

Objective: To examine whether a multidimensional lifestyle intervention was equally effective in children at high risk for obesity development (children of migrant and/or low educational level (EL) parents).

Methods: Cluster-randomised controlled trial ("Ballabeina study"), conducted during one school year (2008/09) in 40 randomly selected preschool classes in Switzerland. The culturally tailored intervention consisted of a physical activity program and lessons on nutrition, media use and sleep. Primary outcomes included BMI and aerobic fitness (20m shuttle run). Secondary outcomes included %body fat, waist circumference and motor agility.

Results: In the total sample (n=652, mean age 5.2±0.6 yrs, 74% migrant, 41% low EL), the intervention reduced %body fat and waist circumference, but not BMI, and improved both physical fitness outcomes. Children of migrant parents benefitted equally from the intervention compared to children of non-migrant parents (p for interaction ≥ 0.7). Similarly, children of low EL parents benefitted equally from the intervention compared to those of middle/high EL parents (p for interaction ≥ 0.2).

Conclusions: This culturally tailored intervention was equally beneficial among preschoolers of migrant and low EL parents compared to their counterparts. It represents a promising approach to reduce adiposity and increase fitness in these children.

Trial Registration: Trial Registration: clinicaltrials.gov NCT00674544

Introduction

The high prevalence of childhood overweight and obesity represents a great public health concern [1]. Children of migrant parents and children of parents with a low educational level (EL, a proxy of socioeconomic status [2]) are considered high risk groups for the development of obesity and of low fitness [3-5], both important cardiovascular risk factors. Unfortunately, interventions in these populations seem to be less effective [5-9]. Therefore, innovative interventions are needed to prevent adiposity and low fitness.

To develop effective approaches in these high risk populations, it is recommended to integrate health promotion programs in the context of the broader social and cultural values [10-12]. However, the few existing prevention studies targeting or including high risk children show inconsistent results [5,13-15]. In addition, previous research has mainly been conducted in Black or Hispanic US minority groups [13-15], but there is a lack of evidence for interventions among multicultural migrant populations as typically found in Europe.

Recently, we demonstrated that our lifestyle intervention study could reduce body fat and enhance aerobic fitness in preschool children both in the French and German speaking regions in Switzerland [16]. The study included a high proportion of children of migrant parents of multicultural origins and/or of low EL parents. Therefore, we examined in this current analysis whether our intervention was equally effective in the two predefined subgroups of high risk children (migrant and/or low EL parents).

Methods

Study design, setting and participants

The Ballabeina study was a cluster-randomised controlled trial conducted in 40 randomly selected public preschool classes in areas with a high migrant population from two different socio-cultural and linguistic regions in Switzerland. The design was performed in accordance with CONSORT guidelines and details of the study protocol have been previously described [16,17]. The study was approved by both cantonal ethical committees and a parent or legal representative of each child provided written informed consent. Preschool classes were the unit for randomisation and intervention. The preschool setting was chosen as all children in Switzerland attend preschool. The study was conducted in the German (city of St. Gallen; 70'000 inhabitants) and the French (urban surroundings of Lausanne; 50'000 inhabitants) speaking regions of Switzerland during the school year 2008/09. Eligibility criteria for the preschool classes included a >40% prevalence of migrant children and no participation in any other prevention project. Children were considered migrants if at least one parent was born outside of Switzerland and low EL was defined if at least one parent had no education beyond mandatory school (9 years) [5,18-22]. For reasons of simplicity, both children of migrant and low EL parents in this study are also named socially disadvantaged. The current study population consists of all children that gave valid consent and were present for baseline examination of one of the primary outcome measures.

Table 1: Baseline characteristics according to parental migrant status and educational level

	Non-migrants (n = 189)	Migrants[1] (n = 526)	p-value	Middle/high EL (n=352)	Low EL[2] (n=241)	p-value
Age [years]	5.1 ± 0.6	5.2 ± 0.6	0.13	5.1 ± 0.6	5.2 ± 0.6	0.52
Girls [%]	53	49	0.41	49	53	0.33
BMI [kg/m^2]	15.5 ± 1.3	15.8 ± 1.6	0.08	15.7 ± 1.4	15.8 ± 1.7	0.20
Overweight[3] [%]	8	13	0.06	9	16	0.009
Migrants [%]				58	95	<0.001
Low EL [%]	7	50	<0.001			
German versus French part of Switzerland [%]	60 vs. 40	43 vs. 57	<0.001	55 vs. 45	38 vs. 62	<0.001

Data are shown as mean ± SD. Baseline differences between groups were calculated by mixed linear or logistic regressions with preschool class as the unit of randomisation.

[1] At least 1 parent born outside Switzerland
[2] At least 1 parent with no education beyond mandatory school (9 years))
[3] Cut-off of the International Obesity Task Force (IOTF)

Abbreviations: EL, educational level; BMI, body mass index

Intervention

The intervention lasted one school year (end of August 2008 to mid-June 2009) and was based on the following four lifestyle behaviours: physical activity (PA), nutrition, media use and sleep. The study was designed to intervene at the individual (children, teachers, and parents) and environmental (school curriculum and built environment) level and focused on changes in education, attitudes and behaviour, and on providing social support.

Children – Children participated in a PA program consisting of four 45 minute sessions of PA per week. The PA lessons aimed to increase aerobic fitness and coordination skills; they were designed to be playful and organised into themes (e.g. "Clown, Spiderman"). The lessons took place in or around the preschool classroom and once a week in the gym. Health promoters gave initially one PA lesson/week which was reduced to twice a month after 4 months. The remaining lessons were provided by the regular preschool teacher. Additionally, there were 22 lessons on healthy nutrition, media use, and sleep. Healthy snacks during recess and healthy treats for anniversaries were promoted. In May 2009, a Ballabeina event was organised with games implementing the main messages of the intervention. Regardless of consent, participation in the intervention was mandatory for all children.

Teachers – Teachers participated in two workshops to learn about the content and the practical aspects of the intervention and in one informal meeting to exchange their experiences. Teachers received the prepared intervention lessons several weeks in advance. They were supported by visits of health promoters and by hands-on training.

Parents – Parents participated in three interactive information and discussion evenings about promotion of PA, healthy food, limitation of TV use and the importance of sufficient sleep. Further support was provided by brochures, funny cards, worksheets, and PA exercises that children brought home. Information leaflets were provided in ten different languages and native speakers of the main foreign languages were available to answer questions. Participation of children in extracurricular activities was also encouraged, but not verified.

Environmental factors – Besides curricular changes, the built environment was adapted to promote PA. Thereby, fixed and mobile equipments such as climbing walls, hammocks, balls, cords, or stilts were installed or provided in and around classrooms, including a “movement corner”.

Control group – The control group did not receive any intervention and continued their regular school curriculum which included one 45 min PA lesson per week in the gym; for the French part, one additional 45 min rhythmic lesson per week was provided corresponding to their regular curriculum. Parents of the control group participated in one information and discussion evening. No financial incentives were provided for either intervention of control group.

Objectives and outcome measurements

We tested the efficacy of the multidimensional lifestyle intervention by comparing participants allocated to intervention group with those in the control group at the end of the intervention. Measurements were performed before (August 2008) and at the end of the intervention (June 2009) by especially trained researchers. All primary and secondary outcomes were measured less than 2 weeks apart and are reported at the individual child level. All outcome measurements are described in detail elsewhere [17].

Primary outcomes included body-mass-index (BMI) and aerobic fitness. Body height and weight were measured according to standardized procedures [17] and BMI was calculated as weight (kg)/height squared (m^2). Children’s height was measured without shoes and weight was measured in underwear. Aerobic fitness was assessed by the 20 m shuttle run test, where the children run back and forth for 20 m with an initial running speed of 8·0 km/h and a progressive 0·5 km/h increase of the running speed every minute. The maximal performance was determined when the child could no longer follow the pace or the child decided itself to stop because of exhaustion. The test results were expressed as stages (one stage is approximately one minute) [23].

Secondary outcomes included additional adiposity measures like %body fat and waist circumference. Percentage body fat was measured by a 4-polar single frequency bioelectric impedance (RJL Systems, Model 101A, Detroit, MI, USA) and calculated according to a validated formula [24]. Waist circumference was measured in the middle of the lower costal arch and iliac crest and did not include clothing. Overweight was defined according to cut-offs of the International Obesity Task Force (IOTF) [25]. An additional fitness measure was motor agility, measured by an obstacle course [26,27]. It includes running from a marking cone to a transversally positioned bench, jumping over the bench, crawling under the bench and running back to the marking cone three times in a row as fast as possible. The test was assessed by the time needed to complete the obstacle course and was measured in seconds.

Statistical analysis

Data are presented by mean ± standard deviations (SD) or percentages. Detailed information about migrant regions was based on the maternal country of birth, but data were similar if the paternal country of birth was used. All comparisons were done using mixed linear and logistic regressions with preschool class (cluster) as random factor. Analyses were performed on an intention to treat basis, using individual children data but adjusting for clustering of outcomes within preschool classes. Effect estimates were adjusted for baseline outcomes, age, sex and linguistic region (German vs. French part of Switzerland). Potential modifications of intervention effects by migrant status or EL were tested at a significance level of 0.05. In addition potential modifications of intervention effects by one of the five migrant regions compared to the other migrant regions were also tested. In a secondary analysis, all effects were also stratified by migrant status or EL group to obtain separate point estimates for the respective subgroups.

Although the study was not designed to make statistical inferences on such interactions, we report on these explorative analyses relating to two predefined subgroups [17]. No *p*-value adjustment for parallel comparisons was made because the focus was on effect estimation and there is considerable correlation between the outcome and the predictor variables considered.

Results

Study population

Overall, 652 preschool children were included in the analysis (mean age 5.2 ± 0.6 yrs, 74% migrant children, 41% children of low EL). The detailed flow-chart has been described elsewhere [16]. There were no differences in age and sex accordingly to parental migrant status or EL, but a higher population of low EL children was overweight. The proportion of children of migrant and low EL parents was higher in the French compared to the German part of Switzerland (**table 1**). This corresponds to the general proportion of the migrant and low EL population in Switzerland. The five most important migrant regions were: Former Yugoslavia (24%), Portugal (18%), rest of Europe (27%), Africa (11%) and rest or the world (20%).

Baseline comparisons

At baseline, children of non-migrant and migrant parents differed in %body fat, waist circumference and agility (all $p \leq 0.014$, **table 1**). Children from middle/high EL and low EL differed only in agility ($p<0.001$, **table 1**). Intervention and control children did not differ in outcome measures at baseline in either subgroup, except for a higher BMI in the intervention group of the children of non-migrant parents ($p=0.043$) (**table 2+3**).

Table 2: Intervention effect (Int vs. Con) and interaction by migrant status on adiposity and fitness outcomes

	Baseline		Follow-up		Adj. changes[1]	*n*	*p*-value	Interaction[2]
	INT	CON	INT	CON				
BMI [kg/m²]								
Non-migrants	15.4 ± 1.2	15.8 ± 1.4	15.3 ± 1.2	15.7 ± 1.3	-0.10 (-0.35, 0.14)	161	0.402	0.849
Migrants	15.8 ± 1.5	15.8 ± 1.7	15.9 ± 1.6	15.9 ± 1.7	-0.05 (-0.18, 0.08)	460	0.470	
Percent body fat[3] [%]								
Non-migrants	22.4 ± 5.7	22.1 ± 6.0	21.1 ± 5.0	22.4 ± 4.8	-1.42 (-2.54, -0.30)	145	0.013	0.966
Migrants	24.3 ± 6.4	24.0 ± 6.9	24.0 ± 6.9	24.6 ± 7.0	-1.14 (-2.06, -0.22)	411	0.015	
Waist [cm]								
Non-migrants	51.9 ± 3.2	52.1 ± 3.4	52.2 ± 2.9	53.3 ± 4.0	-0.86 (-1.52, -0.21)	151	0.010	0.824
Migrants	53.3 ± 4.5	53.0 ± 4.4	53.8 ± 4.5	54.6 ± 5.0	-1.02 (-1.69, -0.36)	437	0.003	
Shuttle run [stages]								
Non-migrants	2.9 ± 1.3	2.8 ± 1.3	4.9 ± 1.7	4.2 ± 1.5	0.55 (0.18, 0.91)	150	0.003	0.085
Migrants	3.0 ± 1.3	3.0 ± 1.4	4.5 ± 1.7	4.3 ± 1.7	0.20 (0.04, 0.45)	416	0.108	
Obstacle course [s]								
Non-migrants	18.5 ± 3.9	18.3 ± 3.2	15.8 ± 3.1	16.3 ± 3.2	-0.67 (-1.35, 0.01)	148	0.053	0.685
Migrants	19.8 ± 4.8	19.6 ± 4.8	16.5 ± 2.7	16.9 ± 3.4	-0.48 (-0.92, -0.03)	409	0.035	

[1] Differences between intervention and control group with preschool class as the unit of randomisation and after adjustment by mixed linear regressions for the baseline value, age, sex, and language region. Data are shown as coefficients (95% confidence interval).
[2] Intervention-group x migration-group
[3] Measured by bioelectric impedance analysis

Abbreviations: BMI, body mass index

Intervention effects and interactions

In the total sample, the intervention reduced %body fat and waist circumference, but not BMI, and improved both physical fitness outcomes [16].

Children of **migrant** and non-migrant parents benefitted equally from the intervention regarding adiposity and fitness measures (*p* for interaction ≥ 0.7). Subgroup analyses revealed that the intervention effects on %body fat and waist circumference were significant in both groups. However, the effects on aerobic fitness were only significant in non-migrants children (with the effect sizes being 19% vs. 7% of the mean baseline values for non-migrant vs. migrant children) and the effects on agility were only significant in migrant children (**table 2**). We also tested if the intervention effect was different in any of the five migrant regions compared to the other migrant regions. Thereby, there were no significant interactions, except for aerobic fitness in children from Africa (*p* for interaction = 0.02). African children benefitted more in aerobic fitness than children from other migration regions. Furthermore, modification of intervention effects by migrant status remained non-significant when using a migrant classification of three categories (both parents non-migrants (26% of the children), one parent migrant (25 %), both parents migrants (49 %) (data not shown).

Low EL children benefitted equally from the intervention compared to middle/high EL regarding adiposity and fitness measures (*p* for interaction ≥ 0.2, table 3) (**table 3**). Subgroup analyses revealed that the intervention effects in the low EL group were generally not significant (smaller *n* in the low EL group), except for waist circumference (*p*=0.02), while there were generally significant in the middle/high EL group. Likewise, effect sizes in the low EL group were generally smaller than in the middle/high EL group. Similarly to the migrant data, results were not altered when using a EL classification of three categories (both parents middle/high EL (62% of the children), one parent low EL (21 %), both parents low EL (17 %) (data not shown).

Discussion

Main results

In the total population, the multidimensional lifestyle intervention reduced body fat and improved aerobic fitness and agility, while no effects on BMI were found[16]. This intervention was equally beneficial among preschoolers of migrant compared to non-migrant parents and among preschoolers of low EL compared to middle/high EL parents. In general, the intervention effect was similar irrespective of the migrant region. Although intervention effects did not differ significantly according to EL, effect sizes in low EL children were generally smaller compared to high/middle EL.

Comparison with other research

These results are in contrast to other data, which show only limited evidence for intervention effects in populations of socially disadvantaged children [7]. Possible reasons for the lack of effect in previous studies could be difficulties to address differences in language, religion, health beliefs, ethnic values or behaviours and socioeconomic situation in these populations [12]. To our knowledge, only two previous studies have specifically addressed the question if the same intervention would be equally effective in socially disadvantaged children. A recent obesity prevention study, conducted in a general population of school children in Germany including a high proportion of migrant children found a significant interaction with a less pronounced effect in migrant children [5]. This study focused on promoting water consumption by providing free access to water (water fountains). On the other hand, a healthy lifestyle intervention study (PA & nutrition) in the US showed that African and white American school children benefitted equally from an intervention and demonstrated positive effects on adiposity and fitness [15].

Despite the fact that the adiposity rebound (at age 4-6) is considered crucial for the development of obesity, only few lifestyle intervention studies have been performed in preschool children. We found three studies in preschoolers that were conducted in high risk populations (low socioeconomic status or US minorities) [6,13,14]. These three studies showed inconsistent results regarding the reduction of BMI and/or body fat. Nemet et al. showed no effect on adiposity in preschoolers from low socioeconomic status [6], and Fitzgibbon et al. demonstrated a reduction of BMI in Black, but not in Hispanic preschool children [13,14]. Generally, the US studies are difficult to compare to our and to other European studies, because they were performed in one specific US minority group while European studies included a culturally diverse migrant population [5,8,9]. In disadvantaged groups, only one previous study in preschoolers assessed aerobic fitness [6], but they used other, less validated measures (10m-shuttle run) and therefore, their effects are difficult to compare to our results.

As far we are aware, our study is the sole randomized control study in a large population of European preschool children, including a high proportion of socially disadvantaged children (migrants and low parental EL). As the population and the European context in Muckelbauer's study were similar to our study, the results from this study are the most comparable to ours and the discordant data between both studies emphasize the need for culturally adapted interventions.

Interpretation of our results

The effects of our intervention are possibly due to the adaption of the program to the population of interest, an element that has been previously highlighted [10]. Our intervention was tailored for a culturally heterogenic target group that is typical of many urban areas in Europe. Consequently, we tried to identify the norms and needs of these diverse cultural groups in different pilot studies or focus groups. Furthermore, written information was provided in ten different languages. The recommendations about PA and nutrition were kept simple and short and used many pictures. They were completed with practical exercises to be implemented at home. Regarding the nutritional recommendations, positive and culturally-independent messages were given (e.g. “drink water” or “turn your screen off when you eat”).

Another important factor is the change of the environment, regarding both, the built environment and the curricular framework [10]. Accordingly, the school equipment in and outside of the schools or our study was adapted to provide a large variety of play opportunities. Furthermore, new social norms were created for children, as the PA and nutrition curriculum was incorporated into the existing preschool curriculum and was mandatory for all children. Thereby, daily PA, regular nutrition lessons and healthy snacks during recreation were considered standard. During school time, parents were encouraged to dress their children adequately to allow outdoor PA.

One of the key factors is the education and the support of school-staff [10]. The teachers involved in our intervention were trained and accompanied by the study personal during the whole school year. In addition, we tried to minimize the additional burden on teachers and increase their motivation by providing financial and counselling support to adapt their school equipment and by giving prepared PA and nutrition lessons.

Another key factor for a successful intervention is parental involvement [10]. In this study, we tried to integrate the parents with an enormous effort. Based on the feedback of teachers during an informal meeting towards the end of the study, we realise that parents were also educated by their children through things learned in the preschool and the recommendations and exercises given home. Despite these enormous efforts to involve parents, we suggest to have reached only a part of them. Only about 30% of the parents attended all three information evenings and discussions during the exchange evenings were sometimes conflict-ridden. In any case, parental involvement could certainly have been improved and additional approaches to enhance parental collaboration should be implemented in future studies.

Nevertheless, there are some unanswered questions that need to be investigated in further studies. Regarding most outcome measures, the effect sizes in the subgroup of low EL children were smaller. We hypothesize that the conditions or the circumstances for low EL families were unequal compared to middle/high EL families [28]. Despite all intervention efforts, perceptions of the importance of a healthy lifestyle may still be different in low EL families and the options to act remained limited as after-school activities often demand efforts in time, support and money.

Table 3: Intervention effect (Int vs. Con) and interaction by educational level on adiposity and fitness outcomes

	Baseline		Follow-up		Adj. changes[1]	*n*	*p*-value	Interaction[2]
	INT	CON	INT	CON				
BMI [kg/m²]								
Middle/high EL	15.6 ± 1.3	15.8 ± 1.5	15.5 ± 1.4	15.8 ± 1.6	-0.11 (-0.29; 0.08)	338	0.253	0.306
Low EL	15.8 ± 1.6	15.8 ± 1.9	16.0 ± 1.6	16.0 ± 1.9	0.04 (-0.15; 0.23)	210	0.677	
Percent body fat[3] [%]								
Middle/high EL	23.3 ± 5.9	23.2 ± 6.6	22.4 ± 5.8	23.6 ± 6.7	-1.29 (-2.33; -0.26)	308	0.015	0.181
Low EL	24.3 ± 6.9	24.3 ± 6.9	24.2 ± 6.9	25.0 ± 7.3	-0.43 (1.63; 0.77)	187	0.486	
Waist [cm]								
Middle/high EL	52.7 ± 3.9	52.8 ± 4.2	53.2 ± 3.9	54.3 ± 4.9	-0.87 (-1.46; -0.27)	324	0.004	0.454
Low EL	53.1 ± 4.7	53.2 ± 4.4	53.5 ± 4.5	54.7 ± 5.3	-1.10 (-2.0; -0.20)	196	0.017	
Shuttle run [stages]								
Middle/high EL	3.0 ± 1.3	30 ± 1.5	4.8 ± 1.6	4.3 ± 1.6	0.37 (0.08; 0.66)	309	0.013	0.058
Low EL	2.8 ± 1.2	2.8 ± 1.3	4.2 ± 1.6	4.3 ± 1.7	-0.05 (-0.36; 0.27)	193	0.777	
Obstacle course [s]								
Middle/high EL	18.7 ± 4.3	18.5 ± 3.6	15.9 ± 2.8	16.7 ± 3.3	-0.71 (-1.32; -0.11)	303	0.021	0.258
Low EL	20.3 ± 4.9	20.3 ± 5.4	16.9 ± 2.8	17.0 ± 3.2	-0.24 (-0.94; 0.46)	189	0.497	

[1] Differences between intervention and control group with preschool class as the unit of randomisation and after adjustment by mixed linear regressions for the baseline value, age, sex, and language region. Data are shown as coefficients (95% confidence interval).
[2] Intervention-group x educational level-group
[3] Measured by bioelectric impedance analysis

Abbreviations: EL, educational level; BMI, body mass index

Implications

The results of the study are encouraging, because socially disadvantaged children have been less accessible to previous interventions. As children from various migration regions and from different socio-cultural and linguistic backgrounds were included, this study could serve as an example for an intervention in a culturally diverse population found in many European countries.

Strengths and Limitations

Strengths of this study are the methodological stringent design in accordance with CONSORT guidelines, the relatively large RCT and the high participation rate. In the current study, the many in-school activities and their mandatory nature most likely played a major role for achieving beneficial effects. The fact that this study was not powered to test interactions could be regarded as a limitation. Another limitation of this study is the use of an indirect measurement of VO_2 to test aerobic fitness. However, the shuttle run test had a good reproducibility in our pilot trial (r=0.84, p<0.001) and laboratory tests would not have been feasible in this epidemiological study.

Conclusion

This culturally tailored intervention was equally effective in preschoolers of migrant and low EL parents compared to their counterparts and therefore might represent a promising approach to reduce adiposity and increase fitness in these children.

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Conflict of interest & financial disclosure

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Discussion

3. General discussion

Main findings

We performed a lifestyle intervention in predominantly migrant preschoolers in two socio-cultural and linguistic different regions in Switzerland. At baseline, physical activity was associated with body fat, aerobic fitness and motor skills. The longitudinal data showed an association between baseline physical activity and prospective changes in aerobic fitness and in motor skills, but not in body fat. We found substantial differences in physical activity and sedentary behaviour, in body fat and in motor skills according to the regional socio-cultural environment (German vs. French speaking part of Switzerland). On the other hand, parental socio-cultural characteristics (migrant status or educational level) had less impact on physical activity and on adiposity, but a high impact on sedentary behaviour. The school-based intervention led to improvements in body fat, aerobic fitness and agility. Using approaches to target a multicultural population, children of migrant or low educated parents benefitted equally from the intervention compared to their respective counterparts.

Associations of physical activity with body fat, aerobic fitness and motor skills

In the current study, physical activity was associated with body fat in the cross-sectional analysis, but it was not associated with prospective changes in body fat. This is in line with previous cross-sectional and longitudinal data[1-3]. In contrast to some other, albeit cross-sectional, data[4,5], we did not confirm a more pronounced association of more intense activities with body fat. In our study, only total physical activity was significantly related to body fat. As other longitudinal studies demonstrated a beneficial effect on changes in body fat[6,7], we hypothesize that a larger amount of physical activity or a longer follow up might be required to induce changes in body fat.

However, the study showed that physical activity was related to aerobic fitness and motor skills at baseline and their improvements over nine months. Previous cross-sectional studies in school children have shown an association between vigorous physical activity and aerobic fitness[4,5,8-10]. Our data in preschoolers also demonstrated that vigorous activities were stronger related to changes in aerobic fitness compared to total or moderate physical activity. Thus, we confirmed the association of vigorous physical activity with aerobic fitness in a longitudinal design and extended it to preschoolers.

The observed weak to moderate associations between physical activity and motor skills are in concordance with previous cross-sectional findings in preschoolers[11-13]. Although it is difficult to draw conclusions about the direction of association between physical activity and motor skills, we suggest that the association is dominated by the impact of physical activity on motor skills. We could not replicate an impact of motor skills on increases in physical activity in young children, but, in contrast, found that higher baseline physical activity was associated with beneficial prospective changes in motor skills. If future studies confirm our results, it appears plausible to argue that in young children, initial high motor skills performance levels per se do not guarantee a more active lifestyle. It seems more likely that an early and continuous promotion of physical activity may be essential.

These findings about the cross-sectional and longitudinal associations of physical activity with body fat, aerobic fitness and motor skills strengthen the benefits of being active beginning in early childhood. They contribute to the current understanding of these relationships at a young age and may add more evidence for public health policies in young children.

Differences according to regional and parental socio-cultural characteristics

Similar to previous findings in older children[14-17], we found differences in lifestyle behaviours and health between preschoolers of migrant or low educated parents compared to their counterparts. Migrant children were less active, watched more TV and had more body fat than non-migrant children. Children of low parental education were also less active, but they showed no differences in body fat. In addition to the differences according to parental characteristics, we found that the regional environment had a major impact in determining physical activity and adiposity of young children. The differences in some behaviours (such as physical activity and sedentary behaviours) and in adiposity between the German and French speaking part amounted to 10% or more. On the other hand, those differences generally ranged from 4-8% between children of migrant and non-migrant parents and between children of low educated and well educated parents. The sole exception to these observation was sedentary behaviour (screen time) where differences were much more pronounced according to parental characteristics.

Our results strengthen the importance of the regional environment. This could be explained by the broader social, cultural, economic and physical environment, within which individual behaviour occurs[18]. Specifically, prevailing cultural norms, attitudes and beliefs[19], social peer networks[20,21] or access to recreation facilities, parks and playgrounds[18] seem to play an important role determining physical activity in children. For example, observed differences in time playing outdoors in the current study may reflect potential disparities in the access to spaces to play between the two regions. Reported barriers to play outside, such as traffic or crime, were less prevalent in the German speaking part compared to the French speaking part. However, parental perception of barriers may also be affected by socio-cultural norms, which is influenced by the social environment. Therefore, future studies should make a priority for community-based programs that influence social norms and priorities, but also include the adaption of the environment and provision of opportunities for recreational activities and outdoor playing.

Effects of a physical activity intervention

Our lifestyle intervention over one school year did not change BMI, but resulted in improvements in aerobic fitness and body fat, both important health determinants. In contrast to reported physical activity, we found no intervention effect on measured physical activity whether it was total, moderate-to-vigorous or vigorous physical activity (data on intensities not shown). Despite this finding, increases in physical activity throughout the year are likely to have occurred in view of the improvements in aerobic fitness and agility. This hypothesis could be further strengthened, as we had demonstrated an association between physical activity and changes in aerobic fitness and agility. The lack of effects on measured physical activity might be in part explained by some methodological limitation (described in chapter 1.4.), the low measurement precision regarding the use of “gliding activities” on bikes, scooters or roller skates[22] or the large intraindividual variability of physical activity[23]. Furthermore, the time for the follow-up measurements at the end of the school year was not very advantageous. The activities in the preschools were probably biased by several end-of-the-year events, as for example eight of the 20 control classes had their sports week during the measurement period and many of the intervention classes decided to “do finally something else than Ballabeina” which was certainly diluting the intervention effect. Overall, the observed improvements in body fat and aerobic fitness point to a combined effect of several potentially modifiable determinants. Therefore, and in view of the substantial decrease in children’s fitness [24-26] and the increase in obesity and body fat[27,28] over the last 20 years, the improvements in aerobic fitness and in body fat in favour of the intervention group are most relevant.

Equal effects in high-risk subgroups

The above mentioned intervention was equally effective in children of migrant or low educated families compared to their counterparts. These results are encouraging, as these children have been less accessible in previous interventions[16,29-32]. Thus, our culturally tailored intervention might represent a promising approach to reduce body fat and increase fitness in these high-risk groups. Nevertheless, the absolute effect sizes in children of low educated families were smaller regarding both body fat and fitness. It has been hypothesized that the conditions or the circumstances for families of a low educational level were unequal compared to families of middle/high educational levels[33]. Despite all intervention measures, perceptions of the importance of a healthy lifestyle may still be different in low educated families and the options to act may remain limited. Possible reasons for that may be for example the demanded time and financial effort for after-school activities. To counteract this problem, we offered sport activities immediately after preschool and in the same area for free to all children. However, other reasons such as parental role modelling and support or common familial activities may not have been modulated by the intervention in these families.

Strengths and limitations

Strengths of the Ballabeina study are the methodological stringent design in accordance with CONSORT guidelines, the relatively large randomized controlled trial and the high participation rate. Further strengths are the multidimensional approach and the rigorous implementation. A novelty of this study is the inclusion of a young population at high risk for the development of inactivity and obesity. This allowed us to test interaction between this high risk groups. But the fact that this study was not powered to test interactions presents a limitation. Furthermore, the different cultural regions in Switzerland offer the opportunity to compare individual and regional determinants within the same country with the same national health policy and climate. Since our investigation is not based on a representative sample, we cannot be certain to draw conclusions for the whole population. Another limitation is that the study lacks a long-term assessment of the observed effects. Ideally, a further continuation of this program into advancing school years should be pursued and its long-term effects evaluated.

Perspectives for implementation

Although the Ballabeina study showed a good efficacy in term of reducing body fat and enhancing aerobic fitness under study conditions, we cannot draw conclusions about how the program would work in real life. As stated in several reviews[30,34], it would be important to know how much of the original efficacy can be retained and then sustained in daily preschool practice, as an intervention under study conditions differs from the implementation under a real world situation. For example, such a stringent methodology (exact curriculum, activity cards for home etc) is difficult to implement in real life, where more autonomy for each teacher is necessary and such a high intensity may not be feasible. Therefore more research is needed to study the effectiveness and also cost-effectiveness of programs as well as their long-term effects. Furthermore, although the study took place in two socio-cultural and linguistic distinct regions and included a multicultural population, there are no data on the transfer of successful interventions to other cultures and it needs to be proven how far such a program can be adopted by other countries. Potential limitations of such programs may be the personal, structural and financial resources as changes of infrastructural conditions, school curricula or social norms are required[30]. Thus, it is important to reach and persuade public and school authorities to render the needed changes possible. A key target group are the teachers. They must be convinced of the benefits of a regular physical activity program. However, more settings such as the community, the health sector and policies have to be integrated, as the efforts and changes that are possible within the school setting are also limited especially under real life situations. Last but not least, the program has to be tailored for the specific needs and conditions of the school so that it will be practicable and enjoyable for teachers, as well as for the children. As many good intervention programs failed in their implementation, every effort should be made to integrate programs, like Ballabeina, in the school system. Another perspective could be the evaluation of single components to know which element is the most effective. However, the effect of an intervention on a specific behaviour might differ if this behaviour is implemented by itself or in combination with other lifestyle behaviour changes.

Conclusions

A multidimensional intervention to promote physical activity and that combines a school-based intervention with parental involvement and environmental changes, is likely to be effective to improve body fat and fitness in preschool children, even in children of migrant and low educated families. As children from different socio-cultural and linguistic backgrounds were included, this study could serve as an example for an intervention in a culturally diverse population found in many European countries. Based on our results, future interventions should continue to adapt their programs to the needs of these high-risk children and extend their approaches to reach especially children of low educated families. Further dissemination of this program could contribute to reduce some aspects of the burden of chronic diseases and of the health inequalities that have risen as a consequence of social inequalities.

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About the author

About the author

Name	Flavia Bürgi
Address	Via Radiras, CH-7031 Laax
Date of birth	4th January1978
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Education

Since 2007	**PhD** in Public Health, Institute of Exercise and Health Sciences, University of Basel	
	PhD thesis: «Physical activity in preschoolers»	
	Supervisors:	PD Dr. Jardena J Puder, University of Lausanne
		PD Dr. Susi Kriemler, University of Basel
	External Expert:	Prof. Willem von Mechelen
	Head of faculty:	Prof. Arno Schmidt-Trucksäss
2005 – 2007	**Master degree** in Exercise and Health Sciences, University of Basel	
	Master thesis: «Bewegungs- und Ernährungsaufgaben für Kinder - Beeinflussende Faktoren des kindlichen Bewegungsverhaltens»	
	Supervisors:	Dr. Markus Gerber, University of Basel
		PD Dr. Lukas Zahner, University of Basel
2002 – 2005	**Bachelor degree** in Sports and Health Sciences, University of Basel	
1993 – 1998	Education for primary teachers, Bündner Lehrerseminar, Chur	
1984 – 1993	Primary and secondary school in Laax	

Language trainings

2008	English: First certificate (university of Basel)
2000	Italian: DALI certificate (Siena, Italy)

Employments

Research

2007 – 2011	PhD Project at the Institute of Exercise and Health Sciences, University of Basel Research and project assistant (project «Ballabeina»)
2006 – 2008	Master Project at the Institute of Exercise an Health Sciences, University of Basel Student and project assistant (project «Kidz-Box»)

Teaching

2005 – 2007	Climbing instructor, Climbing Hall Basel
2003 – 2008	Group fitness instructor (indoor cycling, aqua-gym, aerobic, aqua-fit), Migros Basel
1998 - 2002	Teacher at primary school in Breil/Brigels (GR) and substitutions at other places
1994 - 2007	Ski instructor, Swiss Skischool Flims-Laax-Falera

Further trainings for preschool or sport teachers

Since 2008	Course expert J+S Kids
July 2008	Training week for preschool teachers in health promotion, SWCH Solothurn
June 2008	Training for preschool teachers at the Pädagogischen Hochschule Zürich
April 2008	Talk at the Elternforum Wilchingen (SH)
Sept 2007	Training for preschool teachers as part of the project «Burzelbaum»

Peer-reviewed original publications

1. Niederer I, Kriemler S, Zahner L, **Bürgi F**, Ebenegger V, Hartmann T, Meyer U, Schindler Ch, Nydegger A, Marques-Vidal P, Puder JJ 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, 31;9(1):94

2. Ebenegger V, Marques-Vidal P, Nydegger A, Laimbacher J, Niederer I, **Bürgi F**, Giusti V, Bodenmann P, Kriemler S, Puder JJ Independent contribution of parental migrant status and educational level to adiposity and eating habits of preschool children, *European Journal of Clinical Nutrition*, in press

3. **Bürgi F**, Meyer U, Niederer I, Ebenegger V, Granacher U, Marques-Vidal P, Kriemler S, Puder JJ Sociocultural determinants of adiposity and physical activity in preschool children, *BMC Public Health,* 2010, 10:733

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5. **Bürgi F**, Meyer U, Granacher U, Schindler Ch, Marques-Vidal P, Kriemler S, Puder JJ Relationship of physical activity with motor skills, aerobic fitness and body fat in preschool children: A cross-sectional and longitudinal study (Ballabeina), A cross-sectional and longitudinal study (Ballabeina), *International Journal of Obesity,* 2011, 35 (7):937-44

6. Ebenegger V, Marques-Vidal P, Kriemler S, Nydegger A, Zahner L, Niederer I, **Bürgi F**, Puder JJ Differences in Aerobic Fitness and Lifestyle Characteristics in Preschoolers according to their Weight Status and Sports Club Participation, *Obesity Facts*, submitted

7. Puder JJ, Marques-Vidal P, Schindler C, Zahner L, Niederer I, **Bürgi F**, Nydegger A, Kriemler S Effect of a multidimensional lifestyle intervention on fitness and adiposity in predominantly migrant preschool children (Ballabeina): a cluster randomised controlled trial, *BMJ*, provisional accepted 2011

8. **Bürgi F**, Niederer I, Schindler C, Bodenmann P, Marques-Vidal P, Kriemler S, Puder JJ Effect of a lifestyle intervention on adiposity and fitness in socially disadvantaged subgroups of preschoolers: a cluster-randomized trial (Ballabeina), *Preventive Medicine*, in submission

9. Niederer I, **Bürgi F**, Ebenegger V, Marques-Vidal P, Schindler C, Nydegger A, Kriemler S, Puder JJ Benefits of a lifestyle intervention in adiposity and fitness in high-risk subgroups of preschoolers (Ballabeina), *Obesity*, in submission

Conference abstracts as first author

1. **Bürgi F**, Meyer U, Niederer I, Ebenegger V, Zahner L, Granacher U, Kriemler S, Puder JJ Relationship of socio-cultural factors with physical activity, body fat and physical fitness in preschool children (26566, oral presentation), Swiss Public Health Conference, Zurich, Switzerland, 08/09

2. **Bürgi F**, Meyer U, Niederer I, Ebenegger V, Zahner L, Granacher U, Kriemler S, Puder JJ Relationship of socio-cultural factors with physical activity, body fat and physical fitness in preschool children (26566), 25th International Symposium of Pediatric Work Physiology, Le Touquet, France, 09/09

3. **Bürgi F**, Meyer U, Niederer I, Ebenegger V, Marques-Vidal P, Granacher U, Kriemler S, Puder JJ Relationship of socio-cultural factors with physical activity, body fat and physical fitness in preschool children, Annual Meeting Swiss Society of Endocrinology and Diabetology and of the Association of the Study of Obesity and Metabolism (7, oral presentation), Berne, Switzerland, 11/09

4. **Bürgi F**, Meyer U, Niederer I, Ebenegger V, Granacher U, Marques-Vidal P, Kriemler S, Puder JJ Differences in physical activity and body composition in preschool children according to individual and regional socio-cultural factors (oral presentation), 10th Annual Meeting of the Society for Pediatric Sports Medicine, Berlin, Germany, 02/10

5. **Bürgi F**, Meyer U, Niederer I, Ebenegger V, Granacher U, Marques-Vidal P, Kriemler S, Puder JJ Socio-cultural determinants of adiposity and physical activity in preschool children (Ballabeina), (oral presentation), 2nd Annual Meeting of the Swiss Association of Sports Sciences (SGS), Zurich, Switzerland, 3/10

6. **Bürgi F**, Meyer U, Niederer I, Ebenegger V, Granacher U, Marques-Vidal P, Kriemler S, Puder JJ Relationship of socio-cultural factors with physical activity in preschool children, 3rd International Congress on Physical Activity and Public Health, Toronto, 5/10

7. **Bürgi F**, Meyer U, Zahner L, Schindler C, Marques-Vidal P, Kriemler S, Puder JJ Physical activity and motor performance in preschool children (Ballabeina): A cross-sectional and longitudinal analysis (oral presentation), 2nd joint meeting PWP&NASPEM, Nigara-on-the lake, Ontario, Canada, 9/10

8. **Bürgi F**, Niederer I, Ebenegger V, Schindler C, Bodenmann P, Marques-Vidal P, Kriemler S, Puder JJ Effect of a lifestyle intervention on adiposity and fitness in high-risk subgroups of preschoolers: a cluster-randomized trial (Ballabeina), ECSS Pre Conference Symposium Physical activity and sedentary behaviour interventions for children and young people, Liverpool, UK, 07/11, REACH Group Award for excellence in children's physical activity research, first prize poster competition

9. **Bürgi F**, Niederer I, Ebenegger V, Schindler C, Bodenmann P, Marques-Vidal P, Kriemler S, Puder JJ Effect of a lifestyle intervention on adiposity and fitness in high-risk subgroups of preschoolers: a cluster-randomized trial (Ballabeina), 16th Annual Congress of European College of Sports Sciences (ECSS), Liverpool, UK, 07/11

10. **Bürgi F**, Niederer I, Ebenegger V, Schindler C, Bodenmann P, Marques-Vidal P, Kriemler S, Puder JJ Effect of a lifestyle intervention on adiposity and fitness in high-risk subgroups of preschoolers: a cluster-randomized trial (Ballabeina), 26th International Symposium of Pediatric Work Physiology(PWP), Exeter, UK, 09/11

Awards

Award of the REACH Group for Excellence in Children's Physical Activity Research (First Prize poster competition to **Flavia Bürgi**: "Effect of a lifestyle intervention on adiposity and fitness in high-risk subgroups of preschoolers: a cluster-randomized trial (Ballabeina)", Pre-Conference ECSS, Liverpool, July 2011)