STUDY PROTOCOL

School health programs of physical education and/or diet among pupils of primary and secondary school levels I and II linked to body mass index: A systematic review protocol within the project From Science 2 School

Derrick R. Tanous1,2*, Gerhard Ruedl1, Werner Kirschner1, Clemens Drenowatz3, Joel Craddock4, Thomas Rosemann5, Katharina Wirnitzer1,2,6,7

1 Department of Sport Science, Leopold-Franzens University of Innsbruck, Innsbruck, Austria, 2 Department of Research and Development in Teacher Education, University College of Teacher Education Tyrol, Innsbruck, Austria, 3 Division of Physical Education, University of Education Upper Austria, Linz, Austria, 4 Sydney School of Education and Social Work, The University of Sydney, Sydney, Australia, 5 Institute of Primary Care, University of Zurich, Zurich, Switzerland, 6 Health and Lifestyle Science Cluster Tirol, Subcluster Health/Medicine/Psychology, Tyrolean University Conference, Verbund West, Innsbruck, Austria, 7 Research Center Medical Humanities, Leopold-Franzens University of Innsbruck, Innsbruck, Austria

* derrick.tanous@studentuibk.ac.at

Abstract

The most common causes of death in Western countries today are preventable diseases mainly attributed to daily behavior. It has been well documented that genetics are influential but not the deciding factor for developing non-communicable diseases. Ideally, the public should be educated to perform methods of optimal health and wellbeing independently, meaning that individuals should be in control of their health without relying on others. As behavior is known to be consistent over time, good or poor health behavior will track from childhood into adulthood. Physical activity and diet are permanently linked to the individual’s state of health, and when properly balanced, the effects on personal health summate, resulting in greater benefits from this dual-approach for public health. The objective is to highlight the different approaches (physical intervention, nutritional intervention, and dual-approach of diet and exercise) and identify effective interventions for sustainable body weight and healthy body mass index in school children. A systematic review will be conducted following the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines. The review will assess school-based diet and exercise interventions on children in primary and secondary school levels I and II. Overweight and obesity develop as a result of a prolonged imbalance in the energy balance model, with both physical activity and diet being influential in the fluctuation of body weight. A dual-approach including physical activity and diet could therefore be a very promising method to promote sustainable healthy body weight in school children.
Introduction

The most common causes of death in Western countries are non-communicable diseases (NCDs), which can be mainly attributed to daily lifestyle behaviors [1–11]. Up to 71% of the world’s deaths per year (41 million) are caused by NCDs [12]. Developing the symptoms of NCDs is a slow process that occurs over decades and results in pain and suffering in the long-term for affected individuals and their families, with nine out of the ten leading causes for years lived with disability attributed to NCDs [13]. NCDs are widely known to be preventable, even at a low economic cost [1–3, 6, 7, 9, 12, 14]. It has been well documented that genetics are influential but not the deciding factor for developing chronic (non-communicable) diseases [2, 4, 5, 8, 15–18, 20].

Given the importance of behavior in preventing NCDs, health promotion through proper education on developing and maintaining personal health and wellbeing may be a feasible option to improve the burden of NCDs on nations [14, 19, 21, 22]. Nevertheless, personal health behavior is just one of the determinants of health in addition to genetics, social circumstances, health care, and environmental factors [23, 24].

To maximize personal health care, the public could be educated through competence-oriented health literacy to learn how to control one’s health independently before relying on others, such as commercial suppliers [25]. Two key environments where children grow up and develop their health behaviors are: (1) at home and (2) at school [26]. Schools provide a viable intervention setting, as they allow a large number and variety of children and adolescents to be reached independently of their socio-economic background [4, 8, 10, 21, 27–32]. School settings differ from clinical settings and are well controlled in terms of age groups (school levels), state educational mandate of national curricula, and standardized teacher education at tertiary level (such as University level, specialized University College of Teacher Education). Due to their educational efforts, schools influence lifestyle choices and contribute to developing lifelong health promotion and disease prevention [4, 8, 10, 21, 27–34].

Children and adolescents who are overweight or obese have an increased risk for developing chronic diseases over the lifespan [7, 9, 14, 23, 35–39]. Ruedl et al. 2018 concluded that “evidence-based preventative measures to decelerate the rise in body mass index (BMI) of primary school children should be implemented at the earliest” [40]. Overweight/obesity BMI classification is an indicator for excess body fat suggested by the World Health Organization and Centers for Disease Control and Prevention to classify children and adolescents (underweight, normal, overweight, obese 1–3) [39, 41–43]. In addition to biological and genetic aspects, the BMI category is likely related to the individual’s physical activity (PA) level and diet [39, 41, 42, 44]. According to the energy balance model, excess body fat results from consuming more calories per day than calories burned [45]. Therefore, increasing daily PA levels or making adjustments to diet composition can result in slowing, stopping, or reversing the accumulation of excess body fat [45].

There is strong scientific evidence of the beneficial effects of PA regarding the prevention of chronic disease [1, 3, 4, 6–10, 18, 20, 46–62]. Regular PA or physical exercise is not only the key to achieving optimal health but is considered as “medicine,” which no pill or supplement can replace [1, 3, 4, 6–10, 18, 20, 46–61]. Diet is another fundamental pillar in the development of optimal health and wellness [2, 5, 63–97], which can also function as a “medicine” for health but only if the diet is well-planned and balanced, containing mostly plant-based, whole foods [2, 5, 63–68, 70–85, 87–93, 98–101]. The Academy of Nutrition and Dietetics stated in their position paper that appropriately planned vegetarian, including vegan, diets are healthful, nutritionally adequate, and may provide health benefits for the prevention and treatment of certain diseases and that these diets are appropriate for all stages of the life cycle (pregnancy,
infancy, childhood, adulthood, and old age as well as for athletes) [85]. Moreover, studies have consistently shown that people eating plant-based (vegetarian, vegan) diets have healthier BMI on average compared to people eating a mixed (omnivorous) diet [65–67, 70, 102, 103].

PA interventions, dietary interventions, and the dual-approach (permanent linkage or combination of PA and diet) have been implemented in the school setting to improve BMI and body weight (BW), as children and adolescents spend a great deal of time at school [4, 10, 18, 27, 40, 46, 47, 104–111]. Although PA is known as an effective tool for improving personal fitness and shaping good health, PA interventions in schools have been shown to be insufficient to reverse overweight/obesity in the majority of pupils with the condition [47, 104, 106, 108, 112]. Participation in the compulsory subject of physical education (PE) at school is a well-studied and well-functioning opportunity to begin developing the behaviors that lead to a lifetime of PA [4, 46, 47, 113]. However, PA is just one pillar of health, while diet displays another important pillar of health [1, 3, 6, 7, 9, 10, 25, 80, 114–120]. Moreover, school-based dietary interventions have also been shown to be inconsistent in reversing overweight/obesity in most pupils with the condition [10, 28–31, 112].

Considering overweight and obesity develops from an imbalance between energy intake and expenditure, it would be unlikely to stop, prevent, or reverse the condition by solely focusing on PA or diet [45]. The most promising approach appears to be an interaction of PA and diet as an effective solution for sustaining ideal BW [10, 14, 28–31, 108, 116, 121–123]. PA permanently combined with diet is consistently linked to the individuals’ state of health, and when properly balanced, the effects on personal health summate, resulting in superior benefits from a “dual-approach” [2, 10, 14, 28–31, 47, 63–65, 67, 108, 121, 123, 124]. Achieving sustainable health in children and adolescents, at best, would target overweight/obesity with lifestyle factors that appear every day, naturally [23]. Lifestyle factors, such as physical activity level and diet, can improve health immediately for benefits that also carry over into adulthood and older adulthood and could pass on to following generations as well [19, 25]. Considering the cumulative benefits to overall health, a dual-approach of PA with a plant-based diet appears most promising [1, 3, 6, 7, 9, 10, 25, 28–31, 39, 114, 115, 117–120, 125].

A large number of school-based interventions have targeted health behaviors, including diet and/or PA [10, 28–31, 108, 112, 126–139]. Based on our cumulative expertise, a variety of research on school-based PA interventions or dietary interventions exists. However, from the authors’ experience, the focus of plant-based dietary intervention is expected to be low. Future school-based health interventions should therefore consider investigating the PA and plant-based diet dual-approach. On an international scale, there has yet to be a compilation of interventions on PA, diet/diet type, and both for comparing the most effective strategies to improve BMI and/or BW in school pupils. This review aims to determine the best practice of PA, dietary, or combined PA and dietary intervention in primary and secondary school pupils for improving BMI and/or BW. Therefore, the primary objectives of this investigation are to assess: (i) whether compulsory (curriculum mandated) physical education (PE) is associated with BMI in school pupils; (ii) the minimum duration for compulsory PE to cause a change in BW or BMI in school pupils; (iii) whether additional PA, sports, or exercise intervention (beside compulsory PE) in the school setting is associated with a healthy BMI in pupils; (iv) whether there are differences in the efficacy of school-based physical exercise intervention versus diet intervention in promoting a healthy BMI in pupils. The secondary objectives of this investigation are based on sub-analyses regarding: (a) if the kind of dietary intervention* (Omnivorous: animal products; Whole Food Plant-Based: fruits, vegetables, legumes, and/or whole grains; Other: not related to diet type, e.g., soft drink) implemented in school programs is associated with a healthy BMI in pupils; (b) the long term (one year or more) association of interventional discipline (PA, diet, or dual-approach) with healthy sustainable BW
management; (c) considering the dual-approach, whether there are differences in the efficacy of specific diet scheme types (omnivore vs. vegetarian vs. vegan; diet type definitions based on the Academy of Nutrition and Dietetics [85]) linked to PE for maintaining healthy BW.

Materials and methods

This protocol follows the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol (PRISMA-P) guidelines [140, 141].

Inclusion criteria (2.1)

Types of Studies (2.1.1). We will include all types of randomized controlled trials (RCTs), including factorial, cluster, crossover, and parallel designs. As school settings clearly differ from clinical settings, we will also include non-randomized trials if none of the research questions can be addressed by available randomized controlled trials [142]. The following types of non-randomized trials will be included, if necessary: quasi-randomized controlled trials, controlled before-after studies, and follow-up studies such as inception cohort studies and non-randomized controlled trials.

Types of participants (2.1.2). This review will consider all articles on human pupils aged 5–19 years only in primary school and secondary school levels I and II (or equivalent), with systematic review parts 1 (secondary schools) and 2 (primary schools) separated by school level. The subjects must have a stable or compensated medical condition without physical or cognitive disability (e.g., cannot follow all the amount and magnitude of lessons and exercises planned in PE lessons) and no prescribed medication. Unless results are separated, the following studies will be excluded as we cannot guarantee a bias-free result for these subjects (as they would likely add extreme values to the data): (i) studies addressing both pupils and adults (ii) studies with a whole school approach based on the inclusion aspect of people with disabilities unable to fully participate.

Types of intervention (2.1.3). Interventions of focus must be only school-based and include those related to:

1. PA–possible variations include:
   a. PE–compulsory lessons as part of the curriculum (state mandate).
   b. PA–body movements produced by skeletal muscles that result in energy expenditure, not related to PE (e.g., brain/active break: allows bouts of in-class PA without education, or physically active lessons during the learning task at hand, unrelated to the lesson but occurs simultaneously) [143].
   c. Physical exercise–planned, structured, and repetitive sessions with a final or intermediate objective to improve or maintain physical fitness (physical fitness is a set of attributes that are either health- or skill-related) [143].
   d. Sports–related to the development of humans that require physical effort, skills (development of human capacities), a contest including a contract that is rule-governed, institutionalized, and parties have shared values and interests.
   e. Various combinations of (a)–(d).

2. Dietary: aimed at regulating certain nutrition-related activities or actions that have an impact on food choices and health outcomes, which are not related to increasing BMI in anorexic or underweight youth (e.g. canteen-based, dietary supplement, soft drink reduction) [144].
3. Dual-approach: combination of PA and dietary as one intervention.

**Types of outcomes (2.1.4).** The main outcomes of interest include BMI and BW and must be calculated or measured by the testers, not self-reported. BMI is defined as body mass (BW) in kilograms divided by height in meters squared (kg/m$^2$), or by using imperial units with the equivalent calculation [39, 41, 42]. BMI percentile or Z-score will be accepted if BMI (kg/m$^2$) is not available.

The priority of outcomes includes BMI and BW because these measures are typically assessed in school health-related interventions, as they are cost-efficient, fast, and non-invasive. Moreover, BMI is likely related to the individuals’ PA level and diet, and BW is necessary to control for BMI.

**Timing (2.1.5).** No restriction on years considered.

**Language (2.1.6).** We will include articles reported in English or German language.

**Exclusion criteria (2.1.7).**

- Classes with an extraordinary pedagogical approach focusing on the needs of one or two pupils.
- Specialized school branches targeting physical exercise, sports in general, or a specific discipline of sport.
- Intervention groups targeting only overweight and/or obese pupils.
- Interventions outside of regular school hours.
- Multi-component interventions that are based on theoretical approaches—except in cases where PA and/or dietary is the predominant focus, and the intervention is only supplemented with additional health-related content.
- No comparator/no control group.
- No outcome on BMI or BW.

**Information sources (2.2)**

The following databases will be searched for articles published in English/German: PubMed, EMBASE, Education Source. Planned dates of completing the search include from October 2020 –December 2021.

To aid in the integrity of the search coverage, reference lists of included studies will be scanned as well as relevant reviews identified by the search. A bibliography of included articles will be sent to each member of the review team. PROSPERO (International Prospective Register of Systematic Reviews: https://www.crd.york.ac.uk/PROSPERO/) will be searched to identify similar reviews in progress as well as recently completed reviews to avoid review duplication.

**Search Strategy (2.3)**

Only quantitative, published studies will be sought. There will be no study design, date, or language restrictions included as part of the search. Although the databases may vary in the definition of a text word or standardized subject terms search (e.g., Medical Subject Headings [MeSH]), each database search will follow as closely as possible to that of the given PubMed Advanced search in Table 1. To ensure the most accurate coverage of EMBASE, truncation will be used on singular key terms to remove all additional endings (e.g., plural forms) within
### Table 1. Key terms for PubMed advanced search.

| Population 1 | Population 2 | Intervention | Outcome | Study Design |
|--------------|--------------|--------------|---------|--------------|
| 1. Pupil | 1. First grade | 1. Physical intervention | 1. Body weight [MeSH:NoExp] | 1. Randomized controlled trial |
| 2. Pupils | 2. Second grade | 2. Physical activity | 2. Body weight | 2. Randomised controlled trial |
| 3. Boy | 3. Third grade | 3. Physical activities | 3. Body mass | 3. Randomized Controlled Trial |
| 4. Boys | 4. Fourth grade | 4. Sport | 4. Body mass index | [Publication Type:NoExp] |
| 5. Girl | 5. Fifth grade | 5. Sports | 5. Body mass index | 4. Randomized control trial |
| 6. Girls | 6. Sixth grade | 6. Run | 5. Body mass index | 5. Randomised control trial |
| 7. Children | 7. Seventh grade | 7. Running | 6. BM1 | 6. RCT |
| 8. School children | 8. Eighth grade | 8. Weight lifting | 7. Body weight management | 7. Factorial |
| 9. School kids | 9. Ninth grade | 9. Progressive strength training | 8. Cluster | 8. Crossover |
| 10. Kid | 10. Tenth grade | 10. Progressive resistance training | 9. Parallel | 9. Parallel study |
| 11. Kids | 11. Eleventh grade | | | |
| 12. Adolescent | 12. Twelfth grade | | | |
| 13. Adolescents | 13. Junior high | | | |
| 14. Teen | 14. High school | | | |
| 15. Teens | 15. High schools | | | |
| 16. Teenager | 16. School | | | |
| 17. Teenagers | 17. Schools | | | |
| 18. First graders | 18. Primary school | | | |
| 19. Second graders | 19. Primary schools | | | |
| 20. Third graders | 20. Elementary school | | | |
| 21. Fourth graders | 21. Elementary schools | | | |
| 22. Fifth graders | 22. Secondary school | | | |
| 23. Sixth graders | 22. Secondary schools | | | |
| 24. Seventh graders | 24. Middle school | | | |
| 25. Eighth graders | 25. Middle schools | | | |
| 26. Ninth graders | 26. High intensity exercise | | | |
| 27. Tenth graders | 27. Walking training | | | |
| 28. Eleventh graders | 28. Walking | | | |
| 29. Twelfth graders | 29. Aerobic training | | | |
| 30. Freshmen | 30. Aerobic exercise | | | |
| 31. Sophomore | 31. Anaerobic training | | | |
| 32. Sophomores | 32. Anaerobic exercise | | | |
| 33. Young adult | 33. Endurance exercise | | | |
| 34. Young adults | 34. Endurance training | | | |
| 35. Middle schoolers | 35. Fitness training | | | |
| 36. High schoolers | 36. Fitness exercise | | | |
| 37. Youth | 37. Fitness exercises | | | |
| | | | | |

The text word [tw] search is used for each term independently unless explicitly given as a MeSH term. "Or" is included between each row and "and" is included between each column during the search.

https://doi.org/10.1371/journal.pone.0275012.t001
the search (e.g., Pupil instead of pupil OR pupils). The only limit used will be to exclude conference abstracts from the final hits of EMBASE. The specific search strategy will be created by the team, which includes expertise in sport science, nutrition science, and specialized statisticians, and peer-reviewed by the University of Innsbruck Library to assist in the structure of the search. Five columns: population 1, population 2, intervention, outcome, and study design will be used to include all related articles. The following steps will be used to search each database:

1. all terms will be searched independently (e.g., “boy”) and combined with “or” for each column to create five separate search strings

2. the columns will be combined into one search with “and” linking the five columns (all terms from Population 1 in one string “and” all terms from Population 2 in one string “and” all terms from Intervention in one string “and” all terms from Outcome in one string “and” all terms from Study design in one string).

Study records (2.4)
All retrieved articles from each database will be transferred to Covidence (a systematic review management site: covidence.org), and all hits will be shared with all authors. On Covidence, title/abstract and full-text screening will be performed by the two reviewers working independently with the protocol. Covidence will remove most duplicates of the same report. If there are any conflicts, the reviewers will solve these by discussion using an online audio application. If the conflict cannot be solved, a third reviewer will help make the final decision. Following the title/abstract screening, an included article will move to a full-text screening by two reviewers working independently for agreement with the eligibility criteria.

Assessment will be made of the author’s names, institutions, journal of publication, and results, and multiple reports of the same study will be linked. Contact with authors will be made by email or phone, if necessary, to identify missing information or clarifications for eligibility. Reasons for exclusion will be noted by both reviewers.

Data collection process (2.5)
Two reviewers will collect data extraction through standardized electronic data forms within Covidence (online) platform, and the results of the articles will be collected in MS Office Excel (Version 16.0.14131.20278). The second reviewer will check the outcome extracted to be sure of no missing information or errors in the outcome data collected.

The reviewers are both content area experts, and disagreements will be handled by a third reviewer. If important information cannot be found within the text, the study authors will be contacted by email or phone. Table 2 displays the data items that will be extracted.

Risk of bias (2.6)
If necessary to include non-randomized study designs, the ROBINS-I tool will be used to assess the risk of bias in non-randomized studies as well as quasi-randomized trials and all of the included domains will be assessed for bias with no additional domains [145, 146]. The bias domains include pre-intervention confounding bias, pre-intervention selection bias, at-intervention information bias, post-intervention confounding bias, post-intervention selection bias, post-intervention information bias, and post-intervention reporting bias [146]. Possible confounding domains include age, sex, BMI pre-intervention, BW pre-intervention, school level, school type, school policies on PA and diet, socioeconomic status, school environment, home environment, active transport, food availability, or baseline PA and dietary pattern.
Possible co-interventions include PA education sessions (without performing PA), health counseling unrelated to PA or diet (e.g. drug awareness), cognitive training, or other youth clubs unrelated to PA or diet (e.g. religious groups).

The Cochrane tool as a part of Covidence will be used to assess the risk of bias in randomized studies [147]. Two reviewers will assess included studies independently based on the following:

- Quality of allocation sequence generation
- Quality of treatment allocation concealment from study participants, clinicians, and other health care personnel from enrollment
- Appropriate blinding of the intervention allocation for team members assessing outcomes and data analysis during the trial
- Quality in the completeness of outcome data addressed in the published report for participant exclusions, attrition, and incomplete outcome data

Table 2. Data extraction items.

| Source: | Intervention: |
|---------|--------------|
| • Study ID (if available) | • Total number of intervention groups |
| • Citation and contact details | For each intervention and comparison group of interest: |
| | o Specific intervention |
| | o Type/regimen of physical activity and/or dietary intervention: |
| | o Intervention details (duration, volume, intensity—sufficient for replication, if feasible). |
| | o Integrity of intervention. (may not be reported) |

| Eligibility: | Outcomes: |
|-------------|-----------|
| • Confirm eligibility for review | • Outcomes and time points (i) collected; (ii) reported*: |
| • Reason for exclusion | For each outcome of interest: |
| | o Outcome definition (with diagnostic criteria, if relevant) |
| | o Unit of measurement (if relevant). |
| | o or scales: upper and lower limits, and whether high or low score is good. |

| Methods: | Results: |
|----------|----------|
| • Study design | • Number of participants allocated to each intervention group. |
| • Total study duration | For each outcome of interest: |
| • Sequence generation | o Sample size |
| • Allocation sequence concealment | o Missing participants |
| • Blinding | o Summary data for each intervention group (e.g. 2×2 table for dichotomous data; means and SDs for continuous data). |
| • Other concerns about bias | o Subgroup analyses. (may not be reported) |

| Participants: | Miscellaneous: |
|--------------|----------------|
| • Total number | • Funding source |
| • Setting/school type | • Key conclusions of the study authors |
| • Diagnostic criteria | • Miscellaneous comments from the study authors |
| • Age | • References to other relevant studies |
| • Sex | • Correspondence required |
| • Country (location if available–urban vs. rural) | • Miscellaneous comments by the review authors |

| Comparator: | |
|-------------|----------------|
| • Performance of only dietary or physical activity intervention, or control group with detailed description |

https://doi.org/10.1371/journal.pone.0275012.t002
• Quality of outcome reporting and if there exists evidence of selective outcome reporting which may have affected the study results

• Other possible trial problems that could cause a high risk of bias

We will include a description of the procedure for each domain of bias assessment for every study, including quotes when possible. For each domain, the judgment of the bias will be ranked as “high risk”, “low risk”, or “unclear”. Disagreements will be settled by discussion using an online audio application and, if necessary, a third reviewer. The reviewers will not be blinded to the studies, and agreement between reviewers will not be evaluated.

Data synthesis (2.7)

Data will be synthesized separately for randomized and non-randomized studies (if included). A descriptive summary of included studies will be incorporated into tables based upon the population (average age of participants), intervention (PA, dietary, combination), comparator (type of diet, active control, passive control), outcome (BW, BMI), and study design (PICOS structure). To answer our research questions and sub-analyses, data will be quantitatively synthesized by meta-analysis, if appropriate. For BW and BMI outcomes, the effect size of the interventions will be calculated using standardized mean difference or mean difference analyses (95% confidence intervals (95%-CI)) with a fixed- or random-effects meta-analysis (depending on the level of heterogeneity assessed by \( I^2 \) statistic or methodology). If important data (standard deviation, post-values, change scores, etc.) is not reported in the included articles, calculations will be performed from the available data (standard error, p-value, 95%-CI, etc.), or we will contact the authors. A narrative synthesis will also be performed to explore the relationship and findings both within and between the included studies for the research questions and sub-analyses.

Discussion

Children and adolescents face significant health challenges today, and above all, two globally-scaled health issues of urgent concern have been identified by health experts who coined overweight/obesity as an „epidemic“ and physical inactivity/insufficient levels of PA as a „crisis“[22, 37, 50, 59, 60, 124, 148–152]. Since children cannot achieve good health alone, they need support from adults to help them fulfill their potential and thrive [21–23, 26, 117, 153]. Children are key to a nation’s present and future, considering their future roles in raising families and becoming decision- and policy-makers in different settings. Patterns of behavior and lifestyle are established during childhood and adolescence, affecting health for good or bad based on personal choices immediately and in the future [22, 105, 119, 154, 155]. Currently, poor health behavior and the direction of the development of poor health behavior are public health concerns [1, 26, 50, 117, 153, 156].

According to the Global Burden of Disease Study, dietary risks account for 22% of all deaths among adults (≥ 25 years) in Western countries, with more than half of all diet-related deaths linked to low intakes of fruits and whole grains and the high intake of sodium [86, 120]. The five highest-ranked risk factors of premature death worldwide include: (1) hypertension (13%), (2) tobacco use (9%), (3) high blood glucose (6%), (4) physical inactivity (6%), and (5) overweight/obesity (5%) [57–61, 120, 157, 158]. Physical inactivity raises a serious concern because it also supports excess energy intake from unhealthy food products and items [45, 50, 53, 58, 159], but physical inactivity is not the only source of the NCD problem, as NCDs have been shown to develop in highly physically active people [160].
In addition, BMI is related to health, but a person having a BMI within the normal range can still develop other NCDs (e.g., heart disease, cancer, and/or type II diabetes) [1, 35, 36]. Healthy behavior is learned during childhood, and the window for adopting new healthy behaviors diminishes as people grow older [22, 105, 122, 154, 155, 161]. There are tremendous benefits of living a healthy lifestyle, such as the reduced risk for developing NCDs like cancer, diabetes, and heart disease but also, increased lifespan with a decreased period of disabled years, especially at the end of life [3, 48, 82, 117, 155, 162, 163]. It is, therefore, crucial to teach children a healthy lifestyle as early as possible and offer healthy options in parallel [2, 3, 6, 7, 9, 23, 27, 45, 162–165]. Therefore, early intervention to prevent severe health conditions known to track over time from early childhood into adulthood is key [120].

Although PA is known as an effective tool for improving and shaping good health, PA interventions in schools have been shown to be insufficient to reverse overweight/obesity in the majority of pupils with the disease [47, 104, 106]. More appropriately, without the proper diet, the health benefits of PA are less pronounced [25, 120, 160]. Diet and PA are considered crucial in the fight against overweight/obesity [91], even in children [166], with plant-based diets considered particularly effective to fight overweight/obesity [70, 91, 102, 103, 120, 166–170]. Moreover, information regarding current nutritional trends in children and adolescents (10–19) is limited [25, 120, 171, 172]. To yield maximal health benefits alongside a proper health-promoting diet, PA raises the bar for health even further [1, 3, 6, 7, 9, 10, 25, 108, 114, 115, 117–120, 125, 173]. However, current PA opportunities during regular school hours through curricular PE lessons are limited, or even very low in many countries (up to 2 h per week) [57, 59, 60, 174], mainly due to the primary time resource allocation to other equally major school subjects like Mathematics, English, and/or Science [175–177].

Diet is very important for health, but permanently linking it with PA, sports, and exercise as another lifestyle factor that is a well-known health tool as a minimum recommendation to achieve sustainable, lifelong health and wellbeing generally creates a permanent linkage from childhood to adulthood with greater cumulative lasting effects [6, 7, 25, 94, 111, 114, 115, 117, 122, 155]. This review aims to determine the best practice of PA, dietary, or combined PA and dietary intervention in primary and secondary school pupils for improving BMI and/or BW.

Limitations (3.1)
As school settings are different from clinical settings, it is unknown whether non-randomized study designs will be included in order to address all of our research questions.

Strengths (3.2)
This protocol follows the PRISMA-P guidelines to peak the accuracy, transparency, frequency, and completeness of systematic review and meta-analysis methodology within the multidisciplinary field of sport science, nutrition science, pedagogy, and specialized statistics [140, 141].

Amendments (3.3)
In the event of protocol amendments, the date of each amendment will be accompanied by a description of the change and the rationale.

Supporting information
S1 Checklist.
(DOC)
Acknowledgments

There are no professional relationships with companies or manufacturers who will benefit from the results of the present study.

Author Contributions

Conceptualization: Katharina Wirnitzer.
Methodology: Derrick R. Tanous, Katharina Wirnitzer.
Resources: Thomas Rosemann.
Supervision: Gerhard Ruedl, Werner Kirschner, Clemens Drenowatz, Katharina Wirnitzer.
Writing – original draft: Derrick R. Tanous.
Writing – review & editing: Gerhard Ruedl, Werner Kirschner, Clemens Drenowatz, Joel Craddock, Thomas Rosemann, Katharina Wirnitzer.

References

1. World Health Organization. Global status report on noncommunicable diseases 2010. Available at: https://www.who.int/nmh/publications/ncd_report_full_en.pdf. [accessed 20.01.2020].
2. Campbell TC & Campbell TM II. The China study. Ashland, OR: Blackstone Audio; 2016.
3. Imura H. Life course health care and preemptive approach to non-communicable diseases. Proceedings of the Japan Academy, Series B Physical and Biological Sciences 2013; 89(10): 462–473. https://doi.org/10.2183/pjab.89.462 PMID: 24334510
4. Jamner MS, Spruijt-Metz D, Bassin S, Cooper DM. A Controlled Evaluation of a School-based Intervention to Promote Physical Activity Among Sedentary Adolescent Females: Project FAB. Journal of Adolescent Health 2004; 34:279–289. https://doi.org/10.1016/j.jadohealth.2003.06.003 PMID: 15040997
5. Lynch H, Johnston C, Wharton C. Plant-Based Diets: Considerations for Environmental Impact, Protein Quality, and Exercise Performance. Nutrients 2018; 10(12): pii: E1841. https://doi.org/10.3390/nu10121841 PMID: 30513704
6. Lynch J & Smith GD. A life course approach to chronic disease epidemiology. Annu Rev Public Health 2005; 26:1–35. https://doi.org/10.1146/annurev.publhealth.26.021304.144505 PMID: 15760279
7. Mikkelsen B, Williams J, Rakovac I, Wickramasinghe K, Hennis A, Shin HR, et al. Life course approach to prevention and control of non-communicable diseases. The BMJ 2019; 364:l257. https://doi.org/10.1136/bmj.l257 PMID: 30692103
8. Parrish A, Okley AD, Stanley RM, Ridgers ND. The Effect of School Recess Interventions on Physical Activity A Systematic Review. Sports Med 2013; 43:287–299. https://doi.org/10.1007/s40279-013-0024-2 PMID: 23512170
9. World Health Organization. Preventing noncommunicable diseases. Available at: https://www.who.int/activities/preventing-noncommunicable-diseases. [accessed 19.01.2020].
10. Yuksel H, Sahin FN, Maksimovic N, Drid P, Bianco A. School-Based Intervention Programs for Preventing Obesity and Promoting Physical Activity and Fitness: A Systematic Review. Int. J. Environ. Res. Public Health 2020; 17(1):347. https://doi.org/10.3390/ijerph17010347 PMID: 31947891
11. The World Health Organization. The top 10 causes of death. Available at: https://www.who.int/news-room fact-sheets/detail/the-top-10-causes-of-death. [12.04.2020].
12. The World Health Organization. Noncommunicable diseases. Available at: https://www.who.int/news-room fact-sheets/detail/noncommunicable-diseases. [accessed 29.06.2020].
13. Prynn JE, Kuper H. Perspective on disability and non-communicable diseases in low- and middle-income countries, with a focus on stroke and dementia. Int J Environ Res Public Health 2019; 16 (18):3488.
14. Lewis JE & Schneiderman N. Nutrition, physical activity, weight management, and health. Revista Colombiana de Psiquiatria 2006; Suplemento, vol. XXXV.
15. Lichtenstein P, Holm NV, Verkasalo PK, Iliazo A, Kaprio J, Koskenuo M, et al. Environmental and heritable factors in the causation of cancer—analyses of cohorts of twins from Sweden, Denmark, and
Anselma M, Chinapaw MJM, Altenburg TM. Determinants of child health behaviors in a disadvantaged Wirnitzer K.

Grant C.

Schroeder SA. We can do better—Improving the health of the American People. 

Brown T & Summerbell C. Systematic review of school-based interventions that focus on changing physical activity and dietary interventions. Health Psychology 2011; 30(1):99–109. https://doi.org/10.1037/a0021974 PMID: 21299298

Jiménez-Pavón D, Konstabel K, Bergman P, Ahrens W, Pohlabeln H, Hadjigeorgiou C, et al. Physical activity and clustered cardiovascular disease risk factors in young children: a cross-sectional study (the IDEFICS study). BMC Med 2013; 11:172. https://doi.org/10.1186/1741-7015-11-172 PMID: 23899208

Langille JD & Rodgers WM. Exploring the Influence of a Social Ecological Model on School-Based Physical Activity. Health Educ Behav 2010; 37(6):879–94. https://doi.org/10.1177/1090198110367877 PMID: 20980534

Bentham J, di Cesare M, Bilano V, Zhou B, Stevens GA, et al. World-wide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. Lancet 2017; 390(10113):2627–2642.

Currie C, Zanotti C, Morgan A, Currie D, de Loos M, Roberts C, et al. eds. Social determinants of health and well-being among young people: Health Behaviour in School-aged Children (HBSC) study: international report from the 2009/2010 survey. (Health Policy for Children and Adolescents, No. 6). 2012. Available at: https://www.euro.who.int/en/countries/armenia/publications/social-determinants-of-health-and-well-being-among-young-people.-health-behaviour-in-school-aged-children-hbsc-study. [accessed 22.01.2020]

Schroeder SA. We can do better—Improving the health of the American People. N Engl J Med 2007; 357:1221–1228.

Wrimitzer K. Therapeutic, Probiotic, and Unconventional Foods. Chapter 21: Vegan Nutrition: Latest Boom in Health and Exercise. Elsevier London, UK. (2018).

Anselma M, Chinapaw MJM, Altenburg TM. Determinants of child health behaviors in a disadvantaged area from a community perspective: a participatory needs assessment. Int J Environ Res Public Health 2018; 15(4):644.

Grant C. The Impact of School Health Programmes. K4D Helpdesk Report. Brighton, UK: Institute of Development Studies. (2017).

Brown T & Summerbell C. Systematic review of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity: an update to the obesity guidance produced by the National Institute for Health and Clinical Excellence. Obes Rev 2009; 10:110–141. https://doi.org/10.1111/j.1467-789X.2008.00515.x PMID: 19673306

Wang Y, Cai L, Wu Y, Wilson RF, Weston C, Fawole O, et al. What childhood obesity prevention programmes work? A systematic review and meta-analysis. Obes Rev 2015; 16(7):547–565. https://doi.org/10.1111/obr.12277 PMID: 25983796

De Bourdeaudhuij I, Van Cauwenberge E, Spittaels H, Oppert J-M, Rostami C, Brug J, et al. School-based interventions promoting both physical activity and healthy eating in Europe: a systematic review within the HOPE project. Obes Rev 2011; 12:205–216. https://doi.org/10.1111/j.1467-789X.2009.00711.x PMID: 20122137

Evans CEL, Albar SA, Vargas-Garcia EJ, Xu F. School-based interventions to reduce obesity risk in children in high- and middle-income countries. Adv Food Nutr Res 2015; 76:29–77. https://doi.org/10.1016/bs.afnr.2015.07.003 PMID: 26602571

Flynn MA, McNeil DA, Maloff B, Mutasingwa D, Wu M, Ford C, et al. Reducing obesity and related chronic disease risk in children and youth: a synthesis of evidence with ‘best practice’ recommendations. Obes Rev 2006; 7S:17–66. https://doi.org/10.1111/j.1467-789X.2006.00242.x PMID: 16371076

Garcia-Hermoso A, Alonso-Martinez AM, Ramirez-Velez R, Perez-Sousa MA, Ramirez-Camplillo R, Izquierdo M. Association of physical education with improvement of health-related physical fitness outcomes and fundamental motor skills among youths. A systematic review and meta-analysis. JAMA Pediatrics 2020; 174(6):e200223.
34. Mantjes JA, Jones AP, Corder K, Jones NR, Harrison F, Griffin SJ, et al. School related factors and 1yr change in physical activity amongst 9–11 year old English schoolchildren. *Int J Behav Nutr Phys Act* 2012; 9:153. https://doi.org/10.1186/1479-5868-9-153 PMID: 23276280

35. Khan SS, Ning H, Wilkins JT, Allen N, Carnethon M, Berry JD, et al. Association of body mass index with lifetime risk of cardiovascular disease and compression of morbidity. *JAMA Cardiol* 2018; 3 (4):280–287. https://doi.org/10.1001/jamacardio.2018.0022 PMID: 29490333

36. Steele CB, Thomas CC, Henley SJ, Massetti GM, Galuska DA, Agurs-Collins T, et al. Vital Signs: trends in incidence of cancers associated with overweight and obesity—United States, 2005–2014. *MMWR Morb Mortal Wkly Rep* 2017; 66(39):1052–1058. https://doi.org/10.15585/mmwr.mm6639e1 PMID: 28981482

37. The World Health Organization. Report of the commission on ending childhood obesity. Implementation plan: executive summary. 2017;1–24. Available at: https://apps.who.int/iris/bitstream/handle/10665/259349/WHO-NMH-PND-ECHO-17.1-eng.pdf. [accessed 23.07.2021].

38. Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. *Pediatrics* 1999; 103 (6):1175–1182. https://doi.org/10.1542/peds.103.6.1175 PMID: 1035925

39. The World Health Organization. *Body mass index—BMI*. Available at: https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi. [accessed 02.07.2020]

40. Ruedi G, Ewald P, Niedermeier M, Kirschnner W, Kopp M, Drenowitz C, et al. Long-term effect of migration background on the development of physical fitness among primary school children. *Scand J Med Sci Sports* 2018;1–8. https://doi.org/10.1111/sms.13316 PMID: 30276666

41. Centers for Disease Control and Prevention. *Body Mass Index (BMI)*. Available at: https://www.cdc.gov/healthyweight/assessing/bmi/index.html. [accessed 10.04.2020]

42. The World Health Organization. *BMI-for-age (5–19 years)*. Available at: https://www.who.int/growthref/bmi-for-age/en/. [accessed 02.07.2020]

43. Freedman DS & Sherry B. The validity of BMI as an indicator of body fatness and risk among children. *Pediatrics* 2009; 124(S1):23–34. https://doi.org/10.1542/peds.2008-3586E PMID: 19720664

44. The Global BMI Mortality Collaboration. Body-mass index and all-cause mortality: individual participant-data meta-analysis of 239 prospective studies in four continents. *Lancet* 2016; 388(10046): P776–786. https://doi.org/10.1016/S0140-6736(16)30175-1 PMID: 27243262

45. Yoo S. Dynamic energy balance and obesity prevention. *J Obes Metab Syndr* 2018; 27(4):203–212. https://doi.org/10.7570/jomes.2018.27.4.203 PMID: 31089565

46. Fairclough S & Strattona G. Effects of a physical education intervention to improve student activity levels. *Physical Education and Sports Pedagogy* 2006; 11(1):29–44.

47. Metsällä B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). *The BMJ* 2012; 345:e5888. https://doi.org/10.1136/bmj.e5888 PMID: 23044984

48. Fredriksen PM, Hjelle OP, Mamen A, Meza TJ, Westerberg A.C. The health oriented pedagogical project (HOPP) a controlled longitudinal school-based physical activity intervention program. *BMC Public Health* 2017; 17:370. https://doi.org/10.1186/s12889-017-4282-z PMID: 28454531

49. Timmons BW, Proudfoot NA, MacDonald MJ, Bray SR, Cairney J. The health outcomes and physical activity in preschoolers (HOPP) study: rationale and design. *BMC Public Health* 2012; 12(1):284. https://doi.org/10.1186/1471-2458-12-284 PMID: 22510438

50. Blair SN. Physical inactivity: the biggest public health problem of the 21st century. *Br J Sports Med* 2009; 43:1-2. PMID: 19136507

51. Hills AP, Okely AD, Baur LA. Addressing childhood obesity through increased physical activity. *Nat Rev Endocrinol* 2010; 6(10):543–549. https://doi.org/10.1038/nrendo.2010.133 PMID: 20736922

52. Booth FW, Roberts CK, Laye MJ. Lack of exercise as a major cause of chronic disease. *Compr Physiol* 2012; 2(2):1143–1211.

53. Hespánhol LC Jr., Pillary JD, van Mechelen W, Verhagen E. Meta-analyses of the effects of habitual running on indices of health in physically inactive adults. *Sports Med* 2015; 45(10):1455–1468. https://doi.org/10.1007/s40279-015-0339-y PMID: 26178328

54. Wen CP, Wai JPM, Tsai MK, Yang YC, Cheng TYD, Lee MC, et al. Minimum amount of physical activity for reduced mortality and extended life expectancy: a prospective cohort study. *The Lancet* 2011; 378:1244–53. https://doi.org/10.1016/S0140-6736(11)60749-6 PMID: 21846575

55. Ring-Dimitriou S, von Duviadil SP, Paulweber B, Stadtmann M, LeMura LM, Peak K, et al. Nine months aerobic fitness induced changes on blood lipids and lipoproteins in untrained subjects versus...
65. Orlich MJ, Jaceldo-Siegl K, Sabaté J, Fan J, Singh PM, Fraser GE. Patterns of food consumption among vegetarians and non-vegetarians. Br J Nutr 2014; 112(10):1644–1654. https://doi.org/10.1017/S000711451400261X PMID: 25247790

66. Sabaté J & Wien M. Vegetarian diets and childhood obesity prevention. The American Journal of Clinical Nutrition 2010; 91(5):1525S–1529S. https://doi.org/10.3945/ajcn.2010.28701F PMID: 20237136

67. Weder S, Hoffmann M, Becker K, Alexy U, Keller M. Energy, Macronutrient Intake, and Anthropometrics of Vegetarian, Vegan, and Omnivorous Children (1–3 Years) in Germany (VeCHi Diet study). Nutrients 2019; 11(5): pii: E130. https://doi.org/10.3390/nu11050130 PMID: 30634559

68. Wirmitzer K, Boldt P, Lechleitner C, Wirmitzer G, Leitzmann C, Rosemann T, et al. Health Status of Female and Male Vegetarian and Vegan Endurance Runners Compared to Omnivores-Results from the NURMI Study (Step 2). Nutrients 2018; 11(1): pii: E29. https://doi.org/10.3390/nu11010029 PMID: 30583521

69. Spencer EA, Appleby PN, Davey GK, Key TJ. Diet and body mass index in 38000 Epic-Oxford meat-eaters, fish-eaters, vegetarians and vegans. Int J Obes Relat Metab Disord 2003; 27(6):728–34. https://doi.org/10.1038/sj.ijo.0802300 PMID: 12833118

70. Gomez-Donoso C, Martinez-Gonzales MA, Martinez JA, Gea A, Sanz-Serrano J, Perez-Cueyo FJA, et al. A pro-vegetarian food pattern emphasizing preference for healthy plant-derived foods reduces the risk of overweight/obesity in the SUN cohort. Nutrients 2019; 11(7): pii: E1553. https://doi.org/10.3390/nu11071553 PMID: 31324022

71. Appleby PN & Key TJ. The long-term health of vegetarians and vegans. Proc Nutr Soc 2016; 75(3): 287–93. https://doi.org/10.1017/S0007114515000434 PMID: 26707634

72. Key TJ, Appleby PN, Crowe FL, Bradbury KE, Schmidt JA, Travis RC. Cancer in British vegetarians: updated analyses of 4998 incident cancers in a cohort of 32,491 meat eaters, 8612 fish eaters, 18,298 vegetarians, and 2246 vegans. Am J Clin Nutr 2014; 1:378S–85S.

73. Orlich MJ, Singh PM, Sabaté J, Jaceldo-Siegl K, Fan J, Knutsen S, et al. Vegetarian dietary patterns and mortality in adventist health study 2. JAMA Intern Med 2014; 173(13):1230–1238.

74. Tonstad S, Stewart K, Oda K, Batech M, Herring RP, Fraser GE. Vegetarian diets and the risk of diabetes in the adventist health study-2. Nutr Metab Cardiovasc Dis 2013; 23(4):292–9.

75. Le TT & Sabaté J. Beyond meatless, the health effects of vegan diets: findings from the adventist cohorts. Nutrients 2014; 6:2131–2147. https://doi.org/10.3390/nu6062131 PMID: 24871675
77. Rizzo NS, Jaceldo-Siegl K, Sabaté J, Fraser GE. Vegetarian dietary patterns are associated with a lower risk of metabolic syndrome. The adventist health study 2. *Diabetes care* 2011; 34:1225–1227.

78. Beeson WL, Mills PK, Phillips RL, Andress M, Fraser GE. Chronic disease among seventh-day adventists, a low-risk group. *Cancer* 1989; 64:570–581.

79. Chiu TH, Huang HY, Chiu YF, Pan WH, Kao HY, Chiu JP, et al. Taiwanese vegetarians and omnivores: dietary composition, prevalence of diabetes and IFG; PLoS One. 2014; 9(2):e88547. https://doi.org/10.1371/journal.pone.0088547 PMID: 24523914

80. Li D. Effect of the vegetarian diet on non-communicable diseases. *J Sci Food Agric* 2014; 94(2):169–173. https://doi.org/10.1002/jsfa.6362 PMID: 23965907

81. Cullum-Dugan D & Pawlak R. Position of the academy of nutrition and dietetics: vegetarian diets. *J Acad Nutr Diet* 2015; 115(5):801–10. https://doi.org/10.1016/j.jand.2015.02.033 PMID: 25911342

82. Tuso P, Physician update: total health. *PermJ* 2014; 18(2):58–63. https://doi.org/10.7812/TPP/13-120 PMID: 24694316

83. Tuso P, Ismail M, Ha B, Bartolotto C. Nutritional update for physicians: plant based diets. *PermJ* 2015; 17(2):61–66.

84. Tuso P, Stoll SR, Li WW. A plant-based diet, atherogenesis, and coronary artery disease prevention. *PermJ* 2015; 19(1):62–67.

85. Melina V, Craig W, Levin S. Position of the academy of nutrition and dietetics: vegetarian diets. *J Acad Nutr Diet* 2016; 116(12):1970–1980. https://doi.org/10.1016/j.jand.2016.09.025 PMID: 27886704

86. GBD-Diet-Collaborators. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the global burden of disease study 2017. *Lancet* 2019; 393:1958–1972.

87. Esselstyn CB Jr. Resolving the Coronary Artery Disease Epidemic Through Plant-Based Nutrition. *The Only System Scientifically Proven to Reverse Heart Disease*. London: Penguin Books; 2008.

88. Esselstyn CB Jr. *Prevent and Reverse Heart Disease. The Revolutionary, Scientifically Proven, Nutrition-Based Cure*. London: Penguin Books; 2008.

89. Ornish D. *Dr Ornish’s Program for Reversing Heart Disease. The Only System Scientifically Proven to Reverse Heart Disease Without Drugs or Surgery*. New York: Ivy Books; 1996

90. Rizzo NS, Jaceldo-Siegl K, Sabaté J, Fraser GE. Vegetarian dietary patterns are associated with a lower risk of metabolic syndrome. The adventist health study 2. *Diabetes care* 2011; 34:1225–1227.

91. Ornish D, Brown SE, Scherwitz LW, Billings JH, Armstrong WT, Ports TA, et al. Can lifestyle changes reverse coronary heart disease? *The Lancet* 1990; 331:435–455.

92. Ornish D, Weidner G, Fair WR, Marlin R, Pettenegil EB, Rasin CJ, et al. Intensive lifestyle changes may affect the progression of prostate cancer. *The Journal of Urology* 2005; 174:1065–1070. https://doi.org/10.1097/01.ju.0000184947.49018.73 PMID: 16094059

93. Esselstyn CB Jr, Gendy G, Doyle J, Golubic M, Roizen MF. A way to reverse CAD? *The Journal of Family Practice* 2014; 63(7):356–364. PMID: 25198208

94. McMacken M & Shah S. A plant-based diet for the prevention and treatment of type 2 diabetes. *J Geriatr Cardiol* 2017; 14(5):342–354. https://doi.org/10.11909/j.issn.1671-5411.2017.05.009 PMID: 28630614
102. Key T & Davey G. Prevalence of obesity is low in people who do not eat meat. BMJ 1996; 313:816–7. https://doi.org/10.1136/bmj.313.7060.816 PMID: 8842088

103. Berkow SE & Barnard N. Vegetarian diets and weight status. Nutr Rev 2006; 64:175–88. https://doi.org/10.1111/j.1753-4887.2006.tb00200.x PMID: 16673753

104. Webber LS, Catellier DJ, Lytle LA, Murray DM, Pratt CA, Young DR, et al. Promoting Physical Activity in Middle School Girls Trial of Activity for Adolescent Girls. American Journal of Preventive Medicine 2008; 34(3):173–184. https://doi.org/10.1016/j.amepre.2007.11.018 PMID: 18312804

105. Ruedl G, Greier N, Niedermeier M, Posch M, Prünster V, Faulhaber M, et al. Factors Associated with Physical Fitness among Overweight and Non-Overweight Austrian Secondary School Students. International Journal of Environmental Research and Public Health 2019; 16:4117. https://doi.org/10.3390/ijerph16214117 PMID: 31731515

106. Ruedl G, Franz D, Frühaufl A, Kopp M, Niedermeier M, Drenowatz C, et al. Development of physical fitness in Austrian primary school children. A longitudinal study among overweight and non-overweight children over 2.5 years. Wien Klin Wochenschr 2018; 130:321–327.

107. Ruedl G, Greier K, Kirschner W, Kopp M. Factors associated with motor performance among overweight and nonoverweight Tyrolean primary school children. Wien Klin Wochenschr 2015; 128(1). https://doi.org/10.1007/s00508-015-0887-3 PMID: 26546350

108. Godoy-Cumilla A, Fuentes-Merino P, Diaz-Gonzalez A, Jimenez-Diaz J, Martinez-Vizzaino V, Alvarez-Bueno C, et al. The effects of physical activity and diet interventions on body mass index in Latin American children and adolescents: a systematic review and meta-analysis. Nutrients 2020; 12:1378. https://doi.org/10.3390/nu12051378 PMID: 32408483

109. Drenowatz C, Greier K, Ruedl G, Kopp M. Association between Club Sports Participation and Physical Fitness across 6- to 14-Year-Old Austrian Youth. International Journal of Environmental Research and Public Health 2019; 16:3392. https://doi.org/10.3390/ijerph16183392 PMID: 31547480

110. Greier K, Ruedl G, Weber C, Thöni G, Riechelmann H. Eating behavior and motor performance of 10 to 14-year-old adolescents (Ernährungsverhalten und motorische Leistungsfähigkeit von 10- bis 14-jährigen Jugendlichen). Ernährung und Medizin 2016; 31(4). German.

111. Adom T, De Villiers A, Puoane T, Kengne AP. School-based interventions targeting nutrition and physical activity, and body weight status of African children: a systematic review. Nutrients 2019; 12(1)pii: E95. https://doi.org/10.3390/nu12010095 PMID: 31905832

112. Singhal J, Herd C, Adab P, Pallan M. Effectiveness of school-based interventions to prevent obesity among children aged 4 to 12 years in middle-income countries: A systematic review and meta-analysis. Obesity Reviews 2020; 1–39.

113. Grydeland M, Bergh IH, Bjelland M, Lien N, Andersen LF, Ommundsen Y, et al. Intervention effects on physical activity: the HEIA study—a cluster randomized controlled trial. International Journal of Behavioral Nutrition and Physical Activity 2013; 10:17. https://doi.org/10.1186/1479-5868-10-17 PMID: 23379535

114. Voráčová J, Badura P, Hamričková J, Sigmund E. Unhealthy eating habits and participation in organized leisure-time activities in Czech adolescents. European Journal of Pediatric 2018; 177:1505–1513. https://doi.org/10.1007/s00431-018-3206-y PMID: 30014303

115. Thivel D, Tremblay MS, Katzmarzyk PT, Fogelholm M, Hu G, Maher C, et al. Associations between meeting combinations of 24-hours movement recommendations and dietary patterns of children: A 12-country study. Preventive Medicine 2019; 118:159–165.

116. European Commission. Nutrition and physical activity. 2021 Available at: https://ec.europa.eu/health/nutrition_physical_activity/overview_en. [accessed 23.07.2021].

117. Santaliesa-Pasias AM, Llamas Dios JE, Sprengeler O, Hebestreit A, De Henauw S, Eiben G, et al. Food and beverage intakes according to physical activity levels in European children: the IDEFICS (Identification and prevention of Dietary and lifestyle induced health EffectS in Children and infantS) study. Public Health Nutrition 2018; 21(9):1717–1725. https://doi.org/10.1017/S1368946518000046 PMID: 29457589

118. Galán-López P, Domínguez R, Piuh M, Gísladóttir T, Sánchez-Oliver AJ, Reis F. Evaluation of Physical Fitness, Body Composition, and Adherence to Mediterranean Diet in Adolescents from Estonia: The AdolesHealth Study. International Journal of Environmental Research and Public Health 2019; 16:4479.

119. Drenowatz C & Grier K. Association of Sports Participation and Diet with Motor Competence in Austrian Middle School Students. Nutrients 2018; 10:1837. https://doi.org/10.3390/nu10121837 PMID: 30501115

120. Wirnitzer K. Vegan diet in sports and exercise—health benefits and advantages to athletes and physically active people: a narrative review. Int J Sports Exerc Med 2020; 6:165.
121. Furtado A. Monitoring the activities of the EU platform on diet, physical activity and health. Annual Report European Commission. 2015;1–144. Available at: https://ec.europa.eu/health/sites/default/files/nutrition_physical_activity/docs/2015_report_en.pdf. [accessed 23.07.2021].

122. Independent Accountability Panel. The health of women, children and adolescents is at the heart of transforming our world: empowering accountability. Final reflections report 2021;1–26. Available at: https://iapewec.org/reports/iaap-2021-final-report/. [accessed 23.07.2021].

123. Baranowski T. Why combine diet and physical activity in the same international research? International Journal of Behavioral Nutritional and Physical Activity 2004; 1:2.

124. Yáñez-Ortega JL, Arrieta-Cerdán E, Lozano-Alonso JE, Gil Costa M, Gutiérrez-Araus AM, Cordero-Guevara JA, et al. Prevalence of overweight and obesity in child population. A study of a cohort in Castile and Leon, Spain. Endocrinol Diabetes Nutr 2019; 66(3):173–180.

125. Williams PT. Interactive effects of exercise, alcohol, and vegetarian diet on coronary artery disease risk factors in 9242 runners: the National Runners’ Health Study. Am J Clin Nutr 1997; 66(5):1197–1206. https://doi.org/10.1093/ajcn/66.5.1197 PMID: 9356539

126. Haerens L, Deforche B, Maes L, Stevens V, Cardon G, De Bourdeaudhuij I. Body mass effects of a physical activity and healthy food intervention in middle schools. Obesity 2006; 14:847–854. https://doi.org/10.1038/oby.2006.98 PMID: 16855194

127. Norris E, van Steen T, Direito A, Stamatakis E. Physical activity lessons in schools and their impact on physical activity, educational, health, and cognition outcomes: a systematic review and meta-analysis. Br J Sports Med 2019; 54:826–838.

128. Dobbins M, Husson H, DeCorby K, LaRocca RL. School-Based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. Cochrane Database Syst Rev 2013;(2): CD007651. https://doi.org/10.1002/14651858.CD007651.pub2 PMID: 23450577

129. Bartholomew JB & Jowers EM. Physically active academic lessons in elementary children. Prev Med 2011; 52(S1):51–54. https://doi.org/10.1016/j.pmed.2011.01.017 PMID: 21281672

130. Riley N, Lubans DR, Morgan PJ, Young M. Outcomes and process evaluation of a programme integrating physical activity into the primary school mathematics curriculum: the easy minds pilot randomised controlled trial. J Sci Med Sport 2015; 18:656–61. https://doi.org/10.1016/j.jsams.2014.09.005 PMID: 25304445

131. Norris E, Shelton N, Dunsmuir S, Duke-Williams O, Stamatakis E. Physically active lessons as physical activity and educational interventions: a systematic review of methods and results. Prev Med 2015; 72:116–25. https://doi.org/10.1016/j.pmed.2014.12.027 PMID: 25562754

132. de Greeff JW, Hartman E, Mullender-Wijnsma MJ, Bosker RJ, Doolaard S, Visscher C. Effect of physically active academic lessons on body mass index and physical fitness in primary school children. J Sch Health 2016; 86:346–52. https://doi.org/10.1111/josh.12384 PMID: 27040472

133. Ridgers ND, Timperio A, Cerin E, Salmon J. Compensation of physical activity and sedentary time in primary school children. Med Sci Sports Exerc 2014; 46(8):1564–9. https://doi.org/10.1249/MSS.0000000000002752 PMID: 24492632

134. Naylor P-J, Nettlefold L, Race D, Hoy C, Ashe MC, Higgins JW, et al. Implementation of school based physical activity interventions: a systematic review of methods and results. Prev Med 2015; 72:95–115. https://doi.org/10.1016/j.pmed.2014.12.034 PMID: 25575800

135. Kobes A, Kretschmer T, Timmerman G, Schreuder P. Interventions aimed at preventing and reducing overweight/obesity among children and adolescents: a meta-synthesis. Obes Rev 2018; 19:1065-1079. https://doi.org/10.1111/obr.12688 PMID: 29671938

136. Harris KC, Kuramoto LK, Schulzer M, Retallack JE. Effect of school-based physical activity interventions on body mass index in children: a meta-analysis. Can Med Assoc J 2009; 180:719-726. https://doi.org/10.1503/cmaj.080966 PMID: 19332753

137. Guerra P, Nobre M, Silveira J, Taddei J. The effect of school-based physical activity interventions on body mass index: a meta-analysis of randomized trials. Clinics 2013; 68:1263-1273. https://doi.org/10.6061/clinics/2013(09)14 PMID: 24141844

138. Hung L-S, Tidwell DK, Hall ME, Lee ML, Briley CA, Hunt BP. A meta-analysis of school-based obesity prevention programs demonstrats limited efficency of decreasing childhood obesity. Nutr Res 2015; 35:229-240. https://doi.org/10.1016/j.nutres.2015.01.002 PMID: 25656407

139. Klakk H, Chinpaw M, Heidemann M, Andersen LB, Wedderkop N. Effect of four additional physical education lessons on body composition in children aged 8–13 years: a prospective study during two school years. BMC Pediatr 2013; 13:170. https://doi.org/10.1186/1471-2431-13-170 PMID: 24131778

140. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015 statement. Syst Rev 2015; 4(1):1. https://doi.org/10.1186/2046-4053-4-1 PMID: 25554246
141. Shamseer L, Moher D, Clarke M, Gheradi A, Liberati A, Petticrew M, et al. PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ 2015; 349:g7647. https://doi.org/10.1136/bmj.g7647 PMID: 25555855

142. Reeves BC, Deeks JJ, Higgins JPT, Shea B, Tugwell P, Wells GA. Cochrane Handbook for Systematic Reviews of Interventions (version 6.0). Chapter 24: Including non-randomized studies on intervention effects. Cochrane, 2019. Available at: www.training.cochrane.org/handbook.

143. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Reports 1985; 100(2):126–131. PMID: 3920711

144. Clarys P, Deliens T, Huybrechts I, Deriemaecker P, Vanaelst B, De Keyzer W, et al. Comparison of nutritional quality of the vegan, vegetarian, semi-vegetarian, pesco-vegetarian, and omnivorous diet. Nutrients 2014; 6(3):1318–1332. https://doi.org/10.3390/nu6031318 PMID: 24667136

145. The Cochrane Collaboration. Cochrane Handbook for Systematic Reviews of Interventions (version 6.0). Available at: www.training.cochrane.org/handbook.

146. Greier K, Drenowatz C, Riedl G, Riechelmann H. Association between daily TV time and physical fitness in Austrian schoolchildren. Advances in Nutrition 2015; 6(3):392–398. https://doi.org/10.3945/an.114.006256 PMID: 25894963

147. Lobstein T, Baur L, Uauy R. Obesity in children and young people: a crisis in public health. Obesity Reviews 2004; 5(S1):4–85.

148. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. The Lancet 2012; 380:247–57.

149. Griffiths LJ, Cortina-Borja M, Sera F, Poulou T, Geraci M, Rich C, et al. How active are our children?: findings from the millennium cohort study. BMJ Open 2013; 3:e002893. https://doi.org/10.1136/bmjopen-2013-002893 PMID: 23965931

150. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. The Lancet 2012; 380:247–57.

151. Bailey DP, Fairclough SJ, Savory LA, Denton SJ, Pang D, Deane CS, et al. Accelerometry-assessed sedentary behaviour and physical activity levels during the segmented school day in 10-14-year-old children: the happy study. Eur J Pediatr 2012; 171:1805–13. https://doi.org/10.1007/s00431-012-1827-0 PMID: 22983026

152. di Cesare M, Sorić M, Bovet P, Miranda JJ, Bhatta Z, Stevens G, et al. The epidemiological burden of obesity in childhood: A worldwide epidemic requiring urgent action. BMC Med 2019; 17:1–20.

153. Institute of Medicine (US) Committee on Assuring the Health of the Public in the 21st Century. The Future of the Public’s Health in the 21st Century. Washington (DC): National Academies Press (US); 2002. Chapter 2: Understanding Population health and Its Determinants. Available at: https://www.ncbi.nlm.nih.gov/books/NBK221239/. https://doi.org/10.17226/10548 [accessed 02.12.2020].

154. Moreno LA, Gottrand F, Huybrechts I, Ruiz JR, González-Gross M, DeHenauw S. Nutrition and Lifestyle in European Adolescents: The HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. Advances in Nutrition 2014; 5(5S):615–623.

155. Marques A, Peralta M, Naia A, Loureiro N, de Matos MG. Prevalence of adult overweight and obesity in 20 European countries, 2014. The European Journal of Public Health 2017;1–5.

156. The World Health Organization. Global Health Risks: Mortality and Burden of Disease Attributable to Selected Major Risks. 2009. Available at: https://www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf. [accessed 09.10.2020]

157. Beaglehole R, Bonita R, Alleyne G, Horton R, Li L, Lincoln P, et al. UN High-Level meeting on non-communicable diseases: addressing four questions. Lancet 2011; 378:449–455. https://doi.org/10.1016/S0140-6736(11)60879-9 PMID: 21665266

158. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 2012; 380:219–229. https://doi.org/10.1016/S0140-6736(12)60313-9 PMID: 22818936

159. Enos WF Jr., Beyer JC, Holmes RH. Pathogenesis of coronary disease in American soldiers killed in Korea. JAMA 1995; 158(11):912–914.

160. Michie S, Richardson M, Johnston M, Abraham C, Francis J, Hardeman W, et al. The behavior change technique taxonomy (V1) of 93 hierarchically clustered techniques: building an international...
consensus for the reporting of behavior change interventions. *Ann Behav Med* 2013; 46:81–95. https://doi.org/10.1007/s12160-013-9486-6 PMID: 23512568 162. US Burden of Disease Collaborators. The state of US health, 1990–2010: burden of diseases, injuries, and risk factors. *JAMA* 2013; 310:591–608. https://doi.org/10.1001/jama.2013.13805 PMID: 23842577 163. Wilcox BJ, Suzuki M, Donlon TA, He Q, Grove JS, Masaki K, et al. Optimizing human health span: insights from Okinawa and Hawaii. *Annu Rev Gerontol Geriatr* 2013; 33(1):133–170. 164. Wirnitzer K. From Science 2 School: Sustainably healthy—active & veggie. Research sketch. transfer research <-> school, booklet (Nachhaltig gesund–bewegt & veggie. Forschungsskizze. transfer Forschung <-> Schule, Heft) 2019; 5:S241–243. German. 165. Physicians Committee for Responsible Medicine. *Nutrition for Kids. A Dietary Approach of Lifelong Health (2018-e).* Available at: http://www.pcrm.org/sites/default/files/pdfs/health/Nutrition_for_Kids.pdf. [accessed [06.07.2020]. 166. Vorwerg Y, Petroff D, Kiess W, Blueher S. Physical activity in 3–6 year old children measured by SenseWear Pro*: direct accelerometer in the course of the week and relation to weight status, media consumption, and socioeconomic factors. *PLoS one* 2013;8:e60619. 167. Kahleova H, Levin S, Barnard N. Cardio-metabolic benefits of plant-based diets. *Nutrients* 2017; 9 (8):848. https://doi.org/10.3390/nu9080848 PMID: 28792455 168. Physicians Committee for Responsible Medicine. *Plant-Based Diets. The power of a plant-based diet for good health.* 2021. Available at: https://www.pcrm.org/good-nutrition/plant-based-diets. [accessed 12.01.2021]. 169. Barnard N, Levin SM, Yokoyama Y. A systematic review and meta-analysis of changes in body weight in clinical trials of vegetarian diets. *J Acad Nutr Diet* 2014;2212–2672. 170. Barnard N, Kahleova H, Levin SM. The use of plant-based diets for obesity treatment. *International Journal of Disease Reversal and Prevention* 2019; 2(1):12pp. 171. Ipsos Retail Performance. (2020). *Exploring the explosion of veganism in the United States.* Available at: https://www.ipsos-retailperformance.com/en/vegan-trends/. [accessed 03.10.2020]. 172. Chiorando M. 30% of British shoppers aged 18–24 are vegan or considering it, says poll. An increasing number of young people are ditching animal products. 2018. Available at: https://www.plantbasednews.org/culture/30-british-shoppers-18-24-vegan-considering. [accessed 03.10.2020]. 173. Sweet SN & Fortier MS. Improving physical activity and dietary behaviors with single or multiple health behavior interventions? A synthesis of meta-analyses and reviews. *Int J Environ. Res. Public Health* 2010; 7:1720–1743. 174. Grao-Cruces A, Velazquez-Romero MJ, Rodriguez-Rodriguez F. Levels of physical activity during school hours in children and adolescents: a systematic review. *Int J Environ Res Public Health* 2020; 17(13):4773. https://doi.org/10.3390/ijerph17134773 PMID: 32830760 175. New Public Middle School Curriculum Austria (Lehrplan der Neuen Mittelschule [NMS, 2018]. Inkrafttretungsdatum: 1. September 2018. Anlage 1: Erster Teil. Allgemeines Bildungsziel, Punkt 5. Bildungsbereiche. Gesundheit und Bewegung. Seite 5. Sowie: Sechster Teil. Lehrpläne der einzelnen Unterrichtsgegenstände. Pflichtgegenstand Bewegung und Sport. Beiträge zu Bildungsbereichen. Seite 102.) German. Available at: https://www.ris.bka.gv.at/Dokumente/Bundesnormen/NOR40199276/NOR40199276.pdf. [accessed 01.08.2022]. 176. Public High School Curriculum Austria (Lehrplan AHS Oberstufe ( Sekundarstufe II) (AHS, 2018b) Inkrafttretungsdatum: 9. Jänner 2018. Anlage D: Erster Teil. Allgemeines Bildungsziel, Punkt 5. Bildungsbereiche. Gesundheit und Bewegung. Seite 10.). German. Available at: https://www.bmbwf.gv.at/Themen/schule/schulpraxis/lp/lp_ahs.html. [accessed 01.08.2022]. 177. Austrian Federal Ministry—Education, Science and Research. New Competence-Oriented Curriculum for Primary and Middle Schools. (Bundesministerium—Bildung, Wissenschaft un Forschung [2021]. Pädagogik-Paket—Teilprojekt Lehrpläne NEU: Neue kompetenzorientierte Lehrpläne für Primar- und Sekundarstufe I und Kompetenzerzieher). German.