Generations on the Move:
Intergenerational Exercise and Health Promotion

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In line with the topic of my thesis, I dedicate my dissertation to my family. Every generation equipped me with fundamental values, virtues and lessons, allowing me to become what I always wished to be – a scientist.

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List of abbreviations

AIx@75	Augmentation index corrected for 75 beats per minute
AQoL-8	Assessment of Quality of Life, 8th edition
AVR	Arteriolar-to-venular ration
BMI	Body Mass Index
cDBP	Central diastolic blood pressure
CON	Control group
cPP	Central pulse pressure
CRAE	Central retinal arteriolar equivalent
CRT	Repeated chair rising test
CRVE	Central retinal venular equivalent
cSBP	Central systolic blood pressure
d	Cohen's d
f	Female
FES	Fear of Falling Scale
FMS	Fundamental movement skills
g	Hedge's g
HR	Resting heart rate
IG	Intergenerational group
kg	Kilograms
KOMPIK	Competences and Interests of Children Questionnaire
m	Male
m	Meters
MVPA	Moderate-to-vigorous physical activity
N	Newton
n	Number of participants
p	p-value
pDBP	Peripheral diastolic blood pressure
PG	Peer-group
pSBP	Peripheral systolic blood pressure
PWV	Pulse wave velocity
r	Correlation coefficient
s	Seconds

SD	Standard deviation
SF-36	General Health Questionnaire
SPPB	Short Physical Performance Battery
TGMD-2	Test of Gross Motor Development, 2nd edition
W	Watt

Summary

Background

In light of demographic and societal changes as well as increasing inactivity within the last decades, the intergenerational exercise setting has been gaining attraction as it possesses the potential to becoming an innovative strategy to promote physical activity in children and seniors. Nevertheless, the effects of such intergenerational exercise programs on physical and psychosocial health have not been examined yet.

Aim

This PhD project aimed to examine the effects of an intergenerational exercise intervention on physical and psychosocial health-outcomes in preschool children and residential seniors. In this regard, the effects of the exercise setting were compared to peer-group exercise and control conditions in both generations. Furthermore, specific research on the relationship between various health outcomes and physical activity in children and seniors were evaluated.

Methods

The *Generations on the Move Study* is a five-armed controlled trial with a 25-week physical exercise training intervention and pre- and post-intervention assessments. Six kindergartens with 68 healthy children and five senior homes with 47 residential seniors from Basel-Stadt and surroundings participated in this study. The kindergartens and senior homes were assigned either to an intergenerational (IG), a peer (PG) or a control group (CON). Children were assessed in gross motor skills (TGMD-2), jump performance, handgrip strength as well as micro- and macrovascular health. Social-emotional skills were assessed by kindergarten teachers with a questionnaire (KOMPIK). Seniors performed the Short Physical Performance Battery (SPPB), including gait speed. Central hemodynamics as well as arterial stiffness were also examined. Questionnaires assessing psychosocial wellbeing (SF-36; FES; AQoL-8) were filled in with staff. IG and PG received one comparable exercise session a week lasting 45 minutes for 25 weeks. The training sessions were conducted in the respective institutions, whereby IG children were accompanied to their partnering residence home. Both CON groups received no intervention and were asked to uphold daily habits. Measurements were performed before and after the intervention. Between group differences were calculated using linear regression models.

Results

Children: Our analyses show at least moderate improvements of IG over CON in most main physical performance parameters ($0.45<d\leq1.07$) and no relevant differences in social-emotional skills ($-0.12<d\leq0.14$). Compared to PG, IG showed moderate effects in gross motor skills (TGMD-2: $d=0.58$ [0.13;1.03]) and handgrip strength ($d=0.66$ [0.26;1.07]). Small effects for IG over PG were found in all social-emotional dimensions ($0.25<d\leq0.40$).
Seniors: Moderate to very large improvements in IG compared to CON were found in all physical performance parameters ($0.76<d\leq2.53$) as well as in markers of cardiovascular health ($0.35<d\leq0.56$). Small to large differences in favor of IG over CON are compatible with data in all questionnaires (SF-36: $d=0.94$ [0.28;1.59]; FES: $d=0.89$ [0.21;1.58]; AQoL-8: $d=1.20$

[0.62;1.79]). Data comparing IG to PG show compatibility with trivial to at least moderate effects in favor of IG in SPPB (*d*=0.45 [0.04;0.86]), single task gait speed (*d*=0.40; [0.05;0.74]) and blood pressure ($0.58<d\leq0.63$). IG showed moderate effects in general health score (*d*=0.68 [0.07;1.29]) and small to moderate effects over PG in all AQoL-8 dimensions ($0.23<d\leq0.51$) whereby data is compatible with small to large effects.

Conclusion

Children in the intergenerational group show largest improvements in motor skills while intergenerational seniors benefit especially in functional mobility necessary for everyday life and psychosocial wellbeing. The intergenerational exercise setting is comparable and in certain dimensions superior to peer-group training and is, therefore, a promising strategy to promote physical performance parameters essential for lifelong fitness and health in children while simultaneously challenging their social-emotional learning skills. The maintenance and, more importantly, the improvements in physical health in seniors are very promising insights, speaking in favor of this setting, especially in combination with the improvements in mental health and quality of life. Future fields of research should examine the underlying mechanisms, long-term effects as well as different populations of children and seniors.

Zusammenfassung

Hintergrund

Das generationenverbindende Bewegungssetting konnte in den letzten Jahren aufgrund demographischer und gesellschaftlicher Veränderungen sowie aufgrund der zunehmenden Inaktivität an Attraktivität gewinnen. Das intergenerative Setting besitzt das Potential, eine innovative Strategie zur Förderung körperlicher Aktivität bei Kindern und Senior*innen zu werden. Nichtdestotrotz wurden die physischen und psychosozialen Effekte von solchen intergenerativen Bewegungsprogrammen bisher nicht wissenschaftlich untersucht.

Ziel

Ziel dieses Dissertationsprojektes liegt darin, die Wirkungen einer intergenerativen Trainingsintervention auf die körperliche und psychosoziale Gesundheit von Vorschulkindern und Senior*innen zu untersuchen. In diesem Zusammenhang wurden die Effekte von intergenerativem Training mit denen von altersspezifischem Training und Kontrollgruppen in beiden Generationen verglichen. Darüber hinaus wurden Zusammenhänge zwischen diversen Gesundheitsparameter und körperlicher Aktivität bei Kindern und Senior*innen evaluiert.

Methoden

Die *Generationen in Bewegung-Studie* ist eine fünfarmige kontrollierte Studie mit einer 25-wöchigen Interventionsphase und Prä- und Post-Messungen. Sechs Kindergärten mit 68 gesunden Kindern und fünf Seniorenheime mit 47 residentiellen Senior*innen in Basel-Stadt und Umgebung nahmen teil. Die Kindergärten und Seniorenheime wurden entweder einer intergenerativen (IG), einer altersspezifischen (PG) oder einer Kontrollgruppe (CON) zugeteilt. Die Kinder wurden in der Grobmotorik (TGMD-2), Sprungleistung und Handgriffkraft sowie auf mikro- und makrovaskuläre Gesundheit untersucht. Die sozial-emotionalen Kompetenzen wurden von Kindergärtnerinnen mittels Fragebogen (KOMPIK) beurteilt. Die Senior*innen führten die Short Physical Performance Battery (SPPB) durch, einschliesslich der Gehgeschwindigkeit. Parameter der zentralen Hämodynamik sowie die arterielle Gefässsteifigkeit wurden ebenfalls erhoben. Fragebögen zum psychosozialen Wohlbefinden (SF-36; FES; AQoL-8) wurden mit dem Heimpersonal ausgefüllt. IG und PG erhielten eine vergleichbare, 45-minütige Trainingseinheit pro Woche über 25 Wochen. Die Trainingseinheiten wurden in den jeweiligen Einrichtungen durchgeführt, wobei die IG-Kinder zu ihren Partner-Seniorenheimen begleitet wurden. Beide CON-Gruppen erhielten keine Intervention und wurden gebeten, ihre täglichen Gewohnheiten beizubehalten. Die Messungen wurden vor und nach der Intervention durchgeführt. Gruppenunterschiede wurden mit linearen Regressionsmodellen berechnet.

Resultate

Kinder: Es wurden moderate bis grosse Verbesserungen für IG im Vergleich zu CON in den meisten physischen Leistungsparameter gefunden ($0.45<d\leq1.07$). In den sozial-emotionalen Kompetenzen wurden keine relevanten Unterschiede gefunden ($-0.12<d\leq0.14$). Im Vergleich zu den altersspezifischen Gruppen zeigt IG moderate Verbesserungen der Grobmotorik

(TGMD-2: d=0.58 [0.13;1.03]) sowie der Handgriffkraft (d=0.66 [0.26;1.07]). Kleine Effekte wurden zugunsten der IG in allen sozial-emotionalen Dimensionen gefunden ($0.25<d\leq0.40$). Senior*innen: Moderate bis sehr grosse Verbesserungen in IG über CON konnten für alle physischen Leistungsparameter gefunden werden ($0.76<d\leq2.53$). Positive Effekte konnten ebenfalls in kardiovaskulären Parametern gemessen werden ($0.35<d\leq0.56$). Kleine bis grosse Unterschiede zugunsten von IG über CON konnten in den Fragebögen (SF-36: d=0.94 [0.28;1.59]; FES: d=0.89 [0.21;1.58]; AQoL-8: d=1.20 [0.62;1.79]) erfasst werden. Vergleiche zwischen IG und PG zeigen Kompatibilität der Daten mit trivialen bis mindestens moderaten Effekte zugunsten der IG in der SPPB (d=0.45 [0.04;0.86]) sowie der Gehgeschwindigkeit (d=0.40; [0.05;0.74]). Moderate Effekte wurden für den Blutdruck gefunden ($0.58<d\leq0.63$). IG zeigt moderate Effekte in allgemeiner Gesundheit (d=0.68 [0.07;1.29]) und kleine bis moderate Effekte über PG in allen AQoL-8 Dimensionen ($0.23<d\leq0.51$).

Fazit

Kinder der intergenerativen Gruppe zeigen die grössten Verbesserungen in den motorischen Fähigkeiten, während intergenerative Senior*innen vor allem in einer Zunahme der alltäglichen physischen Funktionalität und dem psychosozialen Wohlbefinden profitieren. Das intergenerative Trainingssetting ist vergleichbar und in bestimmten Dimensionen dem altersspezifischen Training überlegen. Solche Trainingssettings sind somit eine vielversprechende Strategie, um die körperliche Leistungsfähigkeit von Kindern zu fördern, die für lebenslange Fitness und Gesundheit essentiell sind. Gleichzeitig werden die sozial-emotionalen Kompetenzen durch das Setting gefördert. Die Erhaltung und vor allem die Verbesserung der körperlichen Gesundheit bei Senior*innen sind vielversprechende Erkenntnisse, die für dieses Setting sprechen. Dies vor allem in Anbetracht der Wechselwirkungen zwischen Physis und Psyche. Zukünftige Forschungsprojekte sollten die zugrundeliegenden Mechanismen, die Langzeiteffekte sowie unterschiedliche Populationen von Kindern und Senior*innen untersuchen.

Chapter 1

Introduction

Chapter 1 – Introduction to the potential of intergenerational exercise

1.1 Introduction

During the course of the evolutionary process, our species has developed the unique capacity to learn from others. This ability was absolutely crucial for human ecological success as it allowed us to gradually accumulate information across generations, thus propelling us into a constant process of adaptation and discovery [1]. This systematic transfer of knowledge, skills and culture was disrupted in the last quarter of the 20^{th} century due to demographic and societal changes which separated the nuclear family and severed the direct bond between generations [2]. Various approaches have been made to re-establish contact between generations in our modern, industrialized society [2]. One of these approaches aims at promoting exercise and health in both generations; an intervention strategy which has been postulated over a decade ago [3]. The intergenerational exercise setting possesses the potential to enhance the physical as well as psychosocial health and wellbeing of both children and seniors, but has remained unexamined up until now. The following chapters will guide the reader through various topics explaining the underlying rationale and potential behind the intergenerational exercise approach. Starting from the role and importance of physical activity in the youngest and oldest age groups, I will follow by describing synergies between the different generations, their similar needs and the potential which intergenerational programs possess, merging into the rationale and potential of the intergenerational exercise setting. Thereafter, I will present the aims of the *Generations on the Move Study* with its resulting publications until arriving at the final discussion and my outlook and suggestions for further research in this field of exercise science.

1.2 The role of physical activity during childhood

Biological maturation is in full swing during early childhood. The first decade of life is characterized by rapid physical development and the molding of the brain, whereby these two factors are strongly intertwined [4]. Up to the age of five, the cerebellum gradually learns the functions of balance and equilibrium, coordinating muscle activity and muscle tone [5]. These activities are essential for locomotion and rely heavily on sensory feedback from the vestibular, visual and proprioceptive circuits - provided the environment stimulates them sufficiently [4]. The subsequent period between the age of five and ten is defined as the best years for learning. The brain has built the necessary synaptic connections, and by repetition and practice, these neurological pathways are reinforced and become permanent [6]. This is valid also for fine and gross motor skills. Practice and repetition provides the brain with the necessary feedback on the performance, eventually giving way to "feed-forward" where motor skills have been achieved and can be carried out without conscious effort [6]. The environment plays a crucial role in this learning process and ultimately steers the neurological development by expanding and influencing its ability to change, adapt and cope with changing conditions.

The development of muscle strength as well as motor coordination and postural control are cornerstones of childhood maturation, and many factors are associated with either their successful or insufficient development [6]. Exercise and varied movement patterns based on fundamental movement skills (FMS) play a determining, even mandatory, role in this process. FMS are described as the basis of more specialized and complex movement sequences and can be differentiated in locomotor skills and object control skills [7]. Children with pronounced FMS not only show higher participation in organized and non-organized sports [8], they also show better long-term fitness and cardiovascular health values than children with poorly developed FMS [9]. Preschool age is seen as an important stage for the development of such skills especially when considering long-term athletic development models, which encourage children to be exposed to a variety of activities and sports through deliberate play and practice in order to promote their learning process [8]. In contrast, underdeveloped motor skills can lead to serious deficits such as developmental coordination disorder which, in turn, restricts opportunities for children to engage with the environment and receive necessary stimuli to develop and mature not only on a physical but also on a social level [10, 11]. In addition, the development of motor control is also relevant in the prevention of falls and fall-related injuries [12, 13]. During childhood years, falls are the most common type of injury, accounting between 20-25% of emergency visits and are the fourth largest cause of unintentional injury death in children [14]. Exercise and practice of FMS can effectively improve the neuromuscular and somatosensory system and, in turn, reduce falls and fall-related injuries [15].

As prime learning and growth come by and through movement, physical play is the natural setting in which learning occurs. Not only is physical play the gateway to developing motor skills, it is also the ideal setting to learn cognitive, social and emotional competence [16, 17]. Social-emotional skills center on the maintenance of positive engagement in the physical and social environment. They include the control over emotional arousal, cognitive demands and the ability to maintain positive social interactions with peers and adults [18]. Just as developing motor tasks depend on the environment, so do the maturation of social and emotional skills. The more diverse and varied the environment and setting, the more can the development be stimulated and the skill-set diversified and fortified [19]. It is therefore not surprising that the development of motor and social-emotional skills go hand-in-hand. Cognitive functioning and regulation of social-emotional dimensions are coupled through the same brain structures as motor tasks and they both follow several common underlying processes including sequencing, monitoring and planning [4, 20]. Predictively, studies have been able to link well-developed motor capacities to better cognitive functioning and academic abilities [18, 21]. Social-emotional skills and gross motor function have been identified as main contributors to preschoolers' concurrent and later well-being, mental health and school success [18, 22]. Children manifesting difficulties in regulating emotional and social situations oftentimes display delayed motor function and learning deficits. In fact, longitudinal studies of children with motor impairment were able to show disruptive psychosocial symptoms persisting from childhood into adolescence [10, 23].

Despite the important role of movement and physical activity during childhood, recent data shows that, globally, the prevalence of inactivity is on the rise [24]. In Switzerland, 34% of adolescents do not reach activity recommendations [25] and 40.2% are overweight or obese [26]. Although data for very young children is largely lacking, tracking studies show that the probability of remaining sedentary in adolescence and adulthood is significantly stronger than the probability of remaining active [27]. Considering the interplay of cardiovascular disease and exercise, this is an additional aspect to highlight the importance of activity during childhood. Studies demonstrated how risk factors for coronary artery disease and stroke [27] as well as obesity [28, 29] can be developed in early childhood and tend to carry into adolescence and adulthood. Indeed, individuals who maintained activity levels from childhood throughout adolescence into adulthood in a continuous manner not only show better cardiovascular health [30] but also have higher probability of remaining active in adulthood [31]. Primary prevention measures in childhood often aim at treating risk factors associated with cardiovascular events later in life such as obesity, while less is known on the response to exercise and the cardiovascular response in healthy children [32]. Although such primordial prevention strategies, which refer to avoiding the development of risk factors in the first place, have not been thoroughly investigated yet, the behavioral aspect in relation to exercise and activity implies that it is never too young to engage children in exercise activities and promote health-benefiting lifestyles from an early age.

Preschool years are therefore fundamental in creating long-lasting health habits, which include physical activity. A complex cascade of neuroanatomical changes dominate this developmental stage with FMS playing a key role in establishing not only physical health and maturation, but also by providing opportunities for lifelong inclusion and participation in health-benefiting activities and social settings. Therefore, physical activities challenging motor skills while simultaneously putting children into stimulating social settings to support and provoke social and emotional skill development should be fostered in every child's preschool years.

1.3 The role of physical activity in old age

Aging is a complex and multifaceted biological process affecting all bodily systems, including neuromuscular, cardiovascular and cognitive structures. On a neuromuscular level, biological aging is a degenerative process. Cell homeostasis and functional reserves become impaired [33], leading to motoneuron death and fiber denervation, which, in turn, reduces the number of motor units [34]. This degeneration and tissue atrophy progressively accumulates, directly affecting the capacity to produce force and regenerate. Ultimately, the body loses lean muscle mass and, more pronounced, muscle strength [33, 35, 36]. If no counteractive measures are taken, by the age of seventy to eighty, healthy individuals can experience a 20-40% loss of isometric strength. In nonagenarians, losses of up to 50% have been documented [37]. Such substantial losses in strength have direct and detrimental effects on physical functioning, daily life and, consequentially, the ability to live independently [38]. This neuromuscular decline is not linear, but accelerates with age [39] and the occurrence and degree notably differs between individuals. Lifestyle and inactivity determine this decline to a large extent. Exercise interventions have shown promising results, even in the eldest and most sedentary populations [40]. Regular physical activity is able to slow down the breakdown of motoneurons, support muscle health and preserve functional mobility even in very old individuals [33, 40, 41]. With adequate stimuli, average muscle fiber size and, in turn, independent physical ability, can be maintained in old age [34]. Thus, specific exercise programs can be implemented to maintain functionality as well as to prevent falls in the oldest and most inactive populations [42]. Unfortunately, everyday life of individuals living in nursing homes and residential care is strikingly dominated by inactivity. Observations have recorded that elderly in nursing homes spend solely 1% of total awake time in active motion (taking steps), which accounts for less than 10 minutes per day [43].

Apart from neuromuscular declines, relevant changes due to aging and inactivity alter structural and mechanical properties of the vascular system, resulting in the degeneration of the arterial wall [44]. This degeneration brings about a dilatation and stiffening of the large arteries and manifests itself through systolic hypertension [45] and an increased pulse wave velocity (PWV) [46]. About 50% of people aged 60 years and older are affected by hypertension, and cardiovascular diseases such as ischemic heart disease and stroke remain the leading cause of death worldwide [47]. Regular exercise regulates blood pressure through favorable adaptations of the vascular system and heart [48], and higher fitness is associated with reduced arterial stiffness in active as well as sedentary populations [49]. In younger subjects, a clear dose-response relationship could be established between exercise intensities and endothelial function, whereby higher aerobic exercise intensities evoke higher reductions in arterial stiffness [50, 51]. Studies with elderly patients, however, are conflicting as research in the oldest are lacking in this field. Muratani [52] showed that mild to moderate aerobic exercise reduces arterial stiffness in 50-year old individuals, while Deiseroth et al., [53] found no reduction in PWV in 60-year olds at risk of cardiovascular disease after a high-intensity exercise intervention over 12 weeks. This implies that with increasing age and existing cardiovascular diseases, vascular adaptability is potentially reduced. Nevertheless, long-term effects of regular exercise in the oldest-old (≥81 years old) [34] are unknown and reference values need to be defined as they are limited to an upper range of 70 years of age [54]. Since regular exercise, applied long-term, can improve both vascular properties and provoke changes in structure and function [53], we can assume that life-long activity and its continuation is a relevant aspect in reducing cardiovascular risk in old age.

As we have observed in children, one cannot completely isolate the physical and mental health dimensions as they are strongly related. This interrelation is also valid in old age. On one hand, impairments in one's physical functioning and mobility are directly correlated to mortality and institutionalization [55], while on the other hand, they are also strongly linked to a reduction of social activities and interactions as well as a decrease in quality of life [38]. Quality of life and mental health, therefore, are strongly dependent on physical health and vice-versa [56]. Studies were able to show lower health-related quality of life in nursing home residents than in seniors living at home, which can to a large part be traced back to lower physical activity levels in nursing homes as well as low levels of social interactions and loss of independence [57]. Observational studies recording social activities in nursing homes reveal that on average, residents spend only 10% (approximately 100 min.) of their daily awake time in interactions with other people, including caretakers and nursing staff [43]. Whether the physical decline is due to social isolation or the other way around is ultimately determined on an individual level. In both cases, sedentary lifestyles weaken self-efficacy, adding to the already passive behavior in residential settings, which exasperates the vicious cycle of inactivity even more [58].

By influencing either dimension, the physical or social aspect, one can evoke beneficial effects in the corresponding counterpart. Exercise interventions with nursing home residents are able to combat late-life depression while reducing disability status [59] as physical activity increases circulation not only in working muscles but also in the brain. This increased blood flow can explain acute effects on mood [60] and on behavior which influence social interactions [61] and, in turn, improve quality of life.

In conclusion, physical activity, especially structured group-based exercise programs, bring forth a range of benefits for older people, regardless of age or activity status. This is highly relevant not only from an individual and public health perspective, but also from a socio-economic standpoint, especially when considering the shift in the population age structure: according to the United Nations, people over 85 years of age represent the most rapidly growing population group and are projected to triple in number by 2050 [62]. Consequentially, strategies to increase physical health and relieve inactivity-related public health costs is of paramount interest. Unfortunately, studies show that older people's adherence to exercise declines over time and are strongly dependent on social and environmental factors [63]. In order for senior citizens to be intrinsically motivated and truly engaged in the sessions and participate on a long-term basis, new settings and strategies, such as the intergenerational approach, are called for.

1.4 The intergenerational approach to promote exercise and health

Intergenerational learning has been the informal vehicle within families to systematically transfer knowledge, competences, skills as well as behavioral traits and values between generations. The elder generations were respected as preservers and carriers of values, culture, behavior and family uniqueness in both traditional and modern cultures [64]. This social learning between generations is, in essence, the reason behind the evolutionary success story of our species [1]. Our modern world and societal structures, however, have led to the spatial separation of the nuclear family from its expanded counterparts. As a consequence, opportunities for intergenerational learning and support have been reduced, leaving old and young increasingly vulnerable [65]. Due to ever rarer contacts between family members from the opposite ends of the life continuum, young family members miss out on the experiences, wisdom and support which their grandparents could provide. The grandparents, in contrast, are deprived of the direct link to contemporary social events, vitality as well as the sense of belonging, purpose and worthiness that they would receive from their younger family members [66]. The current demographic, social and economic changes have directly impacted the relationship between generations, contributing to intergenerational intolerance and polarization [67]. Scholars in the field of humanities have stated that the solution to this egoism of the individual generations lies within community programs which create opportunities for intergenerational learning, bringing together non-biologically linked children, youth and elderly [68].

Intergenerational programs can include any range of contexts in which young people and elderly come together in a shared activity. It is especially important that the content and purpose of the program satisfies the interests and needs of each generation in the most relevant manner for it to be mutually beneficial. Researchers have analyzed such programs implemented in educational, social, musical and artistic settings and have discovered beneficial effects in both young and old [69-73]. Youth gained not only knowledge and skills, but also grew emotionally by developing their ability for empathy, creativity and openness. The elderly received respect and recognition for their contributions to the community as well as the acknowledgement of their past experiences and achievements, changing their views of the younger generations for the better of both.

The gap in this field now lies in the exercise and health-promoting aspect, which up to date has remained unexamined. Preliminary data indicates that intergenerational relationships influence participants of exercise programs by providing motivation for seniors to exercise more regularly [74], but health-related physical and psychosocial effects have not been examined in neither children nor seniors. Taking into account the previously stated role of exercise in young and old, one is able to recognize not only mutual needs, but also similarities in physical predispositions. Granacher, Muehlbauer [3] in fact describe similarities in net balance and strength performance, as well as similar social needs, in children and seniors, stating that an intergenerational exercise approach could potentially help promote the adoption and maintenance of a health-enhancing fitness program.

Based on the previously presented research on intergenerational settings and the health-benefits from exercise programs in peer-groups, the intergenerational exercise setting possesses a wide span of potential benefits for both generations. Considering children, this approach aims at supporting the previously stated biological maturation process, especially the development of motor skills, coordination and general dexterity and, in turn, their production and transfer of muscular force. The environment should additionally challenge their social-emotional coping mechanisms in order to provide them with a broader spectrum of experiences, thus allowing them to develop their social and emotional skills by interacting with the elderly. The sessions should teach them how to maintain interactions with others, fortify their pro-social behavior, summon their ability to change perspectives and learn empathy and understanding. For the senior participants, the potential of this setting lies in an engaging and fun setting which will disrupt the monotony and isolation of life in residential living and stimulate them to participate in the games and physical exercise. Through their participation, the approach therefore aims at maintaining, if not increasing, overall physical performance and cardiovascular health, thus decelerating the biological aging process. By targeting strength and functional mobility, the exercise sessions could potentially also reduce falls and the resulting individual and societal burdens. Specifically, as the setting of such an intervention will take place in residential living homes, the sessions additionally aim at reducing isolation and increasing quality of life, maintaining overall mental health as well as increasing self-worth and well-being [3, 75, 76].

My thesis, therefore, aims at filling this gap in exercise science by conducting the first exercise-based intervention with preschool children and residential seniors in a mutually beneficial exercise setting.

Chapter 2

Aims of the thesis

Chapter 2 – Aims of the thesis

My PhD project aimed at examining the physical and psychosocial effects of an intergenerational exercise intervention on preschool children and residential seniors compared to peer-group exercise training and control groups. In addition, specific research on the relationship between various health outcomes and physical activity in children and seniors will be evaluated.

Main objective of my PhD project

Main objective	To compare physical and psychosocial health-outcomes of the intergenerational setting to peer-group exercise and control conditions in preschoolers and residential seniors.

Further aims of my PhD project

Aim 1	To examine the differences in physical performance and psychosocial health in old and oldest-old seniors.
Aim 2	To compare motor competence and social-emotional skills in preschoolers according to gender and age.
Aim 3	To examine the effects of a motor skill-based intervention on cardiovascular health in healthy children.

Outline and hypothesis

Publication 1: Beneficial effects of an intergenerational exercise intervention on health-related physical and psychosocial outcomes in Swiss preschool children and residential seniors: A clinical trial

This publication is the main paper which answers the main objective of my thesis.

Publication 2: Physical performance, cardiovascular health and psychosocial wellbeing in elderly compared to oldest-old residential seniors

This publication is a cross-sectional analysis comparing a multitude of health-related parameters between the elderly and the oldest-old. This publication answers the second aim.

Publication 3: A cross-sectional analysis of motor competence and social-emotional skills by gender and age in preschoolers

This publication is a cross-sectional analysis examining preschool children, focusing on age and gender differences in gross motor skills and social-emotional competence. This publication answers the third aim of my thesis.

Publication 4: Effects of a motor skill-based exercise intervention on cardiovascular health in healthy preschoolers

This publication examines the cardiovascular effects of the intervention in order to provide information on the response to exercise as a means of primordial prevention. This publication answers the fourth aim of my thesis.

Chapter 3
Publication 1

Beneficial effects of an intergenerational exercise intervention on health-related physical and psychosocial outcomes in Swiss preschool children and residential seniors: a clinical trial

Authors

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Beneficial effects of an intergenerational exercise intervention on health-related physical and psychosocial outcomes in Swiss preschool children and residential seniors: a clinical trial

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ABSTRACT

Background. Intergenerational exercise possesses the potential to becoming an innovative strategy for promoting physical activity in seniors and children. Although this approach has gained attraction within the last decade, controlled trials on physical and psychosocial effects have not been performed yet.

Methods. Sixty-eight healthy preschool children (age: 4.9 y (SD 0.7)) and 47 residential seniors (age: 81.7 y (7.1)) participated in this five-armed intervention study. All participants were assigned to either an intergenerational (IG), peer (PG) or a control group (CON). Children were tested on gross motor skills (TGMD-2), jump performance and handgrip strength. Social-emotional skills questionnaires (KOMPIK) were assessed by kindergarten teachers. Seniors performed the Short Physical Performance Battery (SPPB), including gait speed. Arterial stiffness parameters were also examined. Questionnaires assessing psychosocial wellbeing were filled in with staff. IG and PG received one comparable exercise session a week lasting 45 minutes for 25-weeks. CON received no intervention. Measurements were performed before and after the intervention.

Results. In children: IG improved all measured physical parameters. When adjusted for baseline values, large effects were observed in favor of IG compared to CON in TGMD-2 (Cohen's $d = 0.78$ [0.33;1.24]) and in handgrip strength ($d = 1.07$ [0.63;1.51]). No relevant differences were found in KOMPIK between groups ($-0.38 < d \leq 0.14$). In seniors: IG showed moderate to very large improvements in all main physical performance ($0.61 < d \leq 2.53$) and psychosocial parameters ($0.89 < d \leq 1.20$) compared to CON.

Conclusion. IG children showed large benefits in motor skills compared to CON while IG seniors benefit especially in psychosocial wellbeing and functional mobility necessary for everyday life. Intergenerational exercise is comparable and in certain dimensions superior to peer group exercise and a promising strategy to integratively improve mental health as well as physical fitness in preschool children and residential seniors.

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Additional Information and Declarations can be found on page 18

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INTRODUCTION

Throughout the human evolutionary process, intergenerational learning has been the informal vehicle within families to systematically transfer information, knowledge, skills and culture between generations (*Hoff, 2007*). The last quarter of the 20th century has brought forth demographic and social changes which disrupted the nuclear family and thus severed the generational ties (*Newman & Hatton-Yeo, 2008*). Intergenerational approaches have been made in social, musical and artistic settings with promising preliminary outcomes in terms of mutual understanding, tolerance and social belonging (*Ganss & Narr, 2010*; *Greger, 2001*; *Miedaner, 2001*; *Schmidt & Tippelt, 2009*). Although the potential of an intergenerational exercise setting to promote physical as well as psychosocial health in children and seniors has been postulated nearly a decade ago (*Granacher et al., 2011a*; *Granacher et al., 2011b*), it has remained unexamined. The combination of the youngest with the oldest of society seems compatible from a variety of standpoints, as they demonstrate similarities in physical predispositions such as net balance and strength performance (*Granacher et al., 2011b*) as well as mutual needs concerning social learning (*Hatton-Yeo, 2007*).

Preschool children are in an active neuromuscular developmental process which affects their postural control and muscular strength. In order to support their biological maturation in the best possible way, exercise and varied movement patterns based on fundamental movement skills have been proven to be beneficial, if not mandatory, for healthy childhood development (*Barbieri & Zaccagni, 2013*; *Sibley & Etnier, 2003*). Childhood play can not only improve motor skill competence and, in turn, physical performance (*Collard et al., 2010*), but has also been proven to be a determining factor of long-term fitness, cardiovascular health and participation in recreational as well as elite sports (*Lloyd et al., 2015*; *Vlahov, Baghurst & Mwavita, 2014*). Additionally, childhood play and physical activity supports social-emotional and cognitive development through promoting language and communication skills, by improving self-control and memory as well as the ability to cooperate and by teaching problem-solving strategies (*De Bock, 2012*; *Hsieh et al., 2017*; *Lin et al., 2021*).

Seniors show similar values in postural control and muscular strength as children (*Granacher et al., 2011a*), but in the elderly this state arises from a decrease in neuromuscular performance (*Naro et al., 2019*) which leads to a loss in postural control and muscular strength (*Terao et al., 1996*). The ageing process and increasing inactivity impacts not only the neuromuscular, but also the cardiovascular system. Changes in structure and mechanical properties of the vascular bed lead to the degeneration of the arterial wall and an increase in arterial stiffness (*Baulmann et al., 2010*; *Laina, Stellos & Stamatelopoulos, 2018*), which manifests itself in systolic hypertension (*McEniery et al., 2005*). Cognitive changes which occur at older age are primarily influenced by environmental factors and lifestyle along with functional changes due to biological effects (*Byun & Kang, 2016*) and can be linked to a decrease in physical and social activities (*Byun & Kang, 2016*). As a result, quality of life starts to decline, independent living cannot be sustained, social interactions are diminished and the occurrence of chronic diseases negatively impact daily activities and overall health (*Byun & Kang, 2016*; *Hollamby, Davelaar & Cadar, 2017*; *Markle-Reid et al., 2016*; *Schneider et al., 2017*). Both long- and short-term research suggest that physical activity and fitness training in the elderly influence brain structure and function positively (*Dishman et al., 2006*), thus combating the aforementioned neurological disorders.

As both age groups have similar physical and psychosocial needs, an intergenerational approach combining muscular function and motor skills appears to be not only an innovative strategy to increase physical performance and health in both generations, but also to support the development of children's social-emotional needs and to improve psychosocial wellbeing and quality of life in seniors. Preliminary data indicates that intergenerational relationships influence participants of exercise programs by providing motivation for seniors to exercise more regularly when children are included and to increase the seniors' self-esteem (*Friedmann & Francine Godfrey, 2007*). Nevertheless, the potential and mutually beneficial effects of such exercise settings have not yet been examined.

The Generations on the Move Study therefore aims at examining the physical and psychosocial effects of an intergenerational exercise training intervention compared to peer group training and control settings in preschool children and residential seniors. We hypothesized that, in an intergenerational approach, both age groups improve health-related physical outcomes more than inactive controls and similar to children and seniors who are active within a peer group. We further hypothesized that improvements in psychosocial parameters are larger in the intergenerational group compared to peer group exercisers and controls.

METHODS

Study design and population

The present study was designed as a five-armed non-randomized controlled trial with a 25-week physical exercise training intervention and pre- and post-intervention assessments. Six kindergartens and five homes for the elderly in Basel-Stadt and surroundings were recruited for the study. The kindergartens and senior homes were assigned either to the intergenerational group (IG), the peer group (PG) or control group (CON). Kindergartens were assigned based on (a) number of children; (b) age of children; (c) migration background of children and; (d) proximity to senior residence homes. Residence homes were allocated based on (a) number of senior participants; (b) age of senior participants and; (c) geographical location of the residence. Children between the ages of 4 and 6 attending the chosen kindergartens without congenital heart defects or any acute diseases were included. Seniors living in the recruited facilities of at least 65 years of age who did not suffer from chronic and/or congenital heart failure, peripheral neuropathy, peripheral arterial occlusive diseases or diabetes mellitus were included. All measurements were non-invasive and performed in the corresponding kindergartens or senior homes. The a priori registered study protocol complies with the ethical standards of the Declaration of Helsinki and was approved by the local ethics committee (Ethikkommission Nordwest- und Zentralschweiz, ethical approval number: 2018-01123; Clinical Trials Registry Identifier: NCT03739385). Seniors and parents of the children signed a written informed consent after receiving all study information.

Intervention

The intervention groups (IG and PG) received a total of 25 weekly exercise sessions lasting 45 min each. As kindergartens and nursing homes have full schedules, 1 session per week was the only feasible option, which also reflects real-life application of the program. The intervention period was distributed over a scholastic year, taking kindergarten holidays into account. The intervention started in autumn, allowing first year preschoolers the necessary time to adjust to the kindergarten as well as their teachers to observe their social-emotional skills.

The intervention consisted mainly of dynamic balance exercises (walking forwards, backwards, sideways, over objects such as ropes or instable surfaces) as well as object control skills such as throwing, aiming, rolling and catching a variety of objects. Additionally, everyday movement patterns for seniors such as sitting down, standing up, or bending to the floor to pick up objects were integrated in the lessons. Movement patterns for children additionally included jumping, hopping and rolling. The focus during all training sessions were the social interactions between participants, either between peers or between seniors and children. Therefore, the exercises were performed in a playful manner, usually in pairs of two or as a whole group. The intervention did not aim at endurance or cardiovascular strain, as it was based on functional movement patterns. All exercise training sessions were conducted by professional exercise coaches and planned in a progressive and variable manner. In order to compare physical activity between groups, all participants in the intervention groups (20 IG children, 16 IG seniors, 26 PG children and 19 PG seniors) were equipped with accelerometers every five weeks. The data indicates that children showed similar exercise intensities between groups during the training sessions (average over 5 sessions: IG children: 22.8 (1.0) min. moderate-to-vigorous activity (MVPA); PG children: 19.5 (0.6) min. MVPA). IG seniors showed lower MVPA than their corresponding PG (average over 5 sessions: IG seniors: 8.1 (1.0) min. MVPA; PG seniors: 17.9 (1.5) min. MVPA). Even though the intervention was planned so that the overall training stimulus in all intervention groups was equal and therefore comparable, the data showed that the PG seniors were more active than their intergenerational counterparts. This can be explained by the IG performing many exercises while in a seated position. Additionally, the accelerometers were clipped to the participants' hips and therefore did not register arm or leg movements performed while seated. Nevertheless, all groups performed the same exercises, practiced the same motor skills and followed the same variations and progressions. The intervention was performed in the corresponding institutions, whereby the IG children were accompanied to their partnering home of the elderly for the sessions. Both CON groups received no exercise intervention and were asked to uphold their daily habits.

Assessment in children

In order to examine the physical as well as social-emotional dimensions, an age-appropriate testing battery including physical performance parameters as well as a questionnaire for social and emotional conduct was applied. We performed all measurements in the respective kindergartens. A team of trained and experienced assessors adhering to standard operation procedures conducted the tests. Kindergarten teachers were included in test standardization for the social-emotional questionnaires. As exercise has a direct effect on hemodynamic measurements, assessments took place on two separate mornings, whereby we assessed motor skill measurements separately from cardiovascular health parameters. This ensured a standardized protocol without interference on the measured parameters.

Physical performance

Maximal strength and power were assessed by handgrip strength and counter movement jump (CMJ). Handgrip strength (N) and rate of force development (N/s) of the dominant hand was assessed using the Leonardo Mechanography GF® (Novotec Medical GmbH) device. Children were asked to squeeze the hand grip device as hard as possible for a total of 5s. The CMJ was performed on a force plate (Leonardo Mechanography® GRFP LT). Children were instructed to jump as high as possible and were allowed to use their arms during the jump. Maximal jump power in relation to their body weight (W/kg) and jump height (cm) by flight time were calculated using raw export data. For both tests, the mean values of two valid measurements were used for statistical analysis.

An adapted version of the "Test of Gross Motor Development 2" (TGMD-2) was used to assess gross motor skills (*Ulrich, 2000*). The test battery is a validated instrument with high test-retest reliability ($r = 0.88$–0.96) (*Hardy et al., 2012*). The entire TGMD-2 battery included 12 motor tasks consisting of six locomotion (run, hop, gallop, leap, horizontal jump and slide) and six object control subtests (stationary dribble, catch, kick, overhand and underhand throw and striking a stationary ball). As sliding, striking and the underhand throw are strongly linked to American sport culture (*Morgan et al., 2013*), those three subtests were not included in our testing battery. Each child performed one familiarization trial and subsequently two rated trials for each of the five locomotor skills and four object control skills. Each category was rated according to a dichotomic scale, rating "0" (fail) or "1" (pass) for each of the criteria. A maximum of 56 points could be achieved for locomotor skills, 22 for object control skills and 78 points for the total TGMD-2 score.

Social-emotional skills

Kindergarten teachers filled out the KOMPIK questionnaire (skills and interests of children questionnaire) for each child before and after the intervention period to assess social-emotional competence. Three dimensions of the validated questionnaire (*Mayr & Bauer, 2014*) were applied for the study: (a) social skills (self-assertion and cooperation), (b) emotional skills (empathy and emotional regulation) as well as (c) wellbeing and social relationships. Each dimension consists of four to seven questions to a child's behavior which were rated with the following scale: (1) "Never/does not apply"; (2) "Rarely"; (3) "Sometimes"; (4) "Mostly/often" and; (5) "Always/very often". On the basis of the individual answers, scores for each dimension and the total score were calculated. Higher scores represent higher developed skills. Maximum scores for social skills are 70 points, 50 points for emotional skills and 55 points for psychological wellbeing and social relationships which results in a total of 175 possible points as KOMPIK total score (*Mayr & Bauer, 2014*).

Assessment in seniors

In order to measure physical as well as psychosocial health, we designed a testing battery consisting of validated, vastly applied clinical screening tools for the elderly, which are indicative for everyday functionality and health. We conducted all measurements in the respective nursing homes. A team of experienced assessors adhering to standard operation procedures conducted the tests. Nursing home staff was included in the test standardization for the questionnaires. All measurements were performed in the morning and the patients were asked to refrain from physical exercise, as well as drinking caffeine or alcohol 12h prior to testing, as these factors can influence cardiovascular outcomes. Patients were furthermore asked to refrain from taking any hypertensive medication the day prior to the measurement. As physical activity has a direct effect on hemodynamic measurements, the cardiovascular measurements were always performed prior to the other physical performance measurements. This ensured a standardized protocol without interference on any parameters.

Physical performance

Functional mobility was assessed using the three sub-tests (balance, gait and repeated chair rising test) of the Short Physical Performance Battery (SPPB), a reliable and validated protocol to objectively measure physical performance of the lower extremities in order to identify individuals at risk of poor lower-body function (*Guralnik et al., 1994*; *Volpato et al., 2011*). All tests were performed without the use of walking aids such as canes, walking frames or another person for support.

For the balance test, three different stances had to be held for a total of 10s each: Side-by-side, semi-tandem, and tandem stance. A maximum of 4 points can be achieved in the balance sub-test, whereby the scores are attributed as (a) 0 points: not able to hold the stance for 10s or not attempting the stance; (b) 1 point: holding the side-by-side for 10s; holding the semi-tandem stance for 10s; holding the tandem stance between 3 and 9.99s and; (c) 2 points: holding the tandem stance for the entire 10s (*Guralnik et al., 1994*).

For gait speed, time over 10 m was recorded with timing gates (Witty System) in a single- as well as dual-task situation from which average gait speed was calculated (m/sec.), whereby a split time at 4 m was additionally recorded. Seniors were asked to walk at their habitual walking speed. During dual-task, seniors counted backwards out loud, starting from 50 in the first and from 70 in the second trial. Each walking condition was performed twice and mean values of the tests were used for statistical analysis. The 4 m split time during single-task condition was used for scoring according to cut-off times of the SPPB protocol: 0 points for not being able to walk 4 m distance; 1 point: >8.7s; 2 points: 6.21–8.7s; 3 points: 4.82–6.20s; 4 points: ≤4.82s (*Guralnik et al., 1994*).

The repeated chair rising test (CRT) is a well-established geriatric test to assess lower-limb power and functionality (*Hellmers et al., 2019*) and was performed on a force plate (Leonardo Mechanography® GRFP LT) with a 46 cm high locked bench. The force plate records time per repetition as well maximal power during every stand-to-sit cycle. Participants were asked to fully stand up and sit back down as fast as possible without pushing off the bench with their hands. Total time for 5 repetitions (seconds) as well as relative peak power (W/kg) were calculated using raw data exports. The mean of two valid measurements were used for statistical analysis. The total time for 5 sit-to-stand cycles were additionally scored between 1 and 4 points according to SPPB protocol: 1 point: >16.7s; 2 points: 13.7–16.69s; 3 points: 11.2–13.69s; 4 points: ≤11.19s (*Guralnik et al., 1994*).

These three sub-tests are used to calculate the SPPB total score (maximum score of 12 points), which is highly predictive for disability, hospitalization, institutionalization and mortality in community-dwelling elderly, whereby lower scores indicate higher level of disability (*Volpato et al., 2011*).

Cardiovascular health

Blood pressure and arterial stiffness parameters were obtained using an oscillometric Mobil-O-Graph® PWA Monitor device (I.E.M. GmbH, Stoberg, Germany) with integrated ARCSolver® software. From the measurements, central blood pressure as well the augmentation index corrected for 75 bpm (AiX@75) and pulse wave velocity (PWV) were exported. The blood pressure cuff was placed on the left upper arm while the patient was in a resting seated position. Three valid measurements were taken and the mean values of all three tests calculated and used for data analysis.

Psychosocial wellbeing and quality of life

Participants filled out three questionnaires with the help of the research and nursing staff: the general health questionnaire (SF-36), the assessment of quality of life 8 dimensions (AQoL-8D) as well as the fear of falling questionnaire (FES). The SF-36 is a validated and reliable questionnaire consisting of eight categories yielding a summary on physical as well as mental health (*Ware Jr, 2000*). A higher score in all categories represents higher general health. The AQoL-8D is a reliable and valid tool to assess quality of life (*Richardson et al., 2014*) in seniors. The questionnaire examines the following dimensions in a total of 35 items: independent living, pain, mental health, life satisfaction, coping, relationships, self-worth and senses. The "senses" dimension was not integrated in the applied questionnaire. The lower the sum in all dimensions, the better is the psychosocial state of an individual. The FES questionnaire consists of 16 questions and is used to assess probability of falling in the elderly (*Yardley et al., 2005*). The higher the score (range: 16–64), the more severe is the concern about falling.

Statistical analysis

Data of all groups is shown as mean with standard deviations (SD). Mean differences in pre-post data for each study arm was calculated with paired t-Tests corresponding 95% confidence intervals (95% CI). Confidence intervals for the pre-post changes in each study arm were estimated by bootstrapping with 5000 re-samples. This analysis was performed by means of estimationstats.com (*Ho et al., 2019*). Additionally, in order to establish the effects of the intervention groups (IG and PG) compared to control conditions (CON), linear regression models were calculated for each parameter with the respective CON group as model reference. In all analysis, pre-test data as well as age was used as covariate in order to adjust for baseline values. Using the estimates and SD of baseline parameters, effect sizes

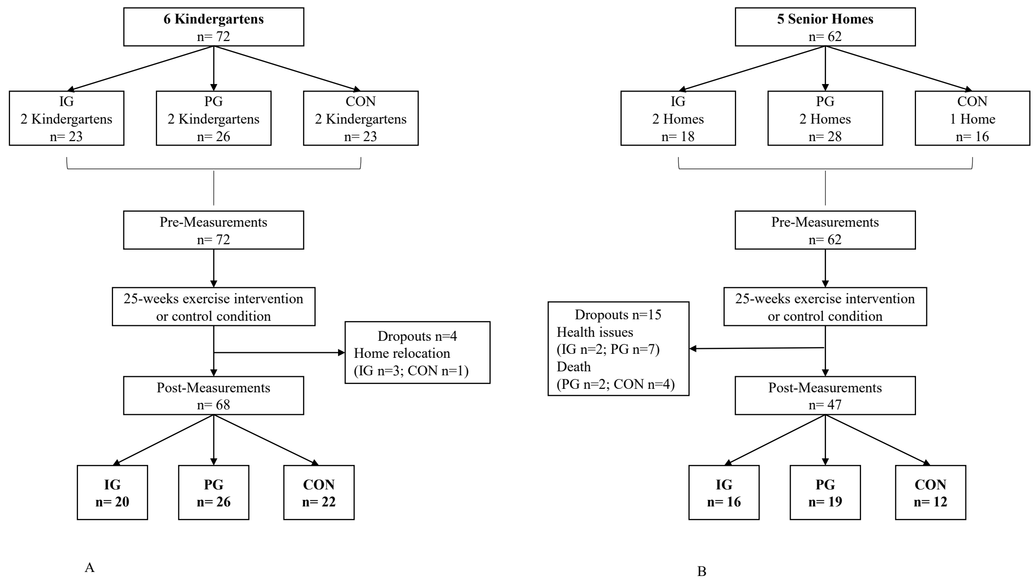

Figure 1 **(A) Flow Chart of the study for child participants; (B) Flow Chart of the study for senior participants.**

Full-size DOI: 10.7717/peerj.11292/fig-1

(Cohen's d) with 95% confidence intervals were calculated and can be interpreted as trivial ($d<0.2$), small ($0.2\leq d<0.5$), moderate ($0.5\leq d<0.8$) and large ($d\geq 0.8$) (*Cohen, 1992*).

RESULTS

Study population

A total of six kindergartens including 72 children and five homes for the elderly with a total of 62 seniors participated in the study. During the study period, four children (6%) and 15 seniors (24%) dropped out due either to home relocation, personal health issues or death. This resulted in a total of 68 children who completed the trial, whereof 20 were in the intergenerational group (IG), 26 in the peer group (PG), and 23 in the control group (CON). A total of 47 seniors completed the study, whereof 16 were in IG, 19 in PG and 12 in CON (Fig. 1). Baseline data for both populations are shown in Table 1.

Children

Physical performance

Changes from pre- to post-test in physical performance parameters of children from all groups are shown in Table 2. Large pre-post differences for IG were found in maximum jump power, handgrip strength and total TGMD-2 score. Linear regression models showed at least moderate improvements of IG compared to CON in most main parameters ($0.45<d\leq 1.07$). Object control ($d=0.45$ [−0.05;0.96]) and jump height ($d=0.29$ [−0.06;0.63]) showed only small improvements in IG relative to CON and a negligible effect in jump power ($d=0.11$ [−0.30;0.51]). Due to the wide confidence intervals, no explicit statements can be made for PG compared to IG or CON (Fig. 2).

Table 1 Baseline data for children and senior participants for all groups.

	IG Children $n=20$	PG Children $n=26$	CON Children $n=22$	IG Seniors $n=16$	PG Seniors $n=19$	CON Seniors $n=12$
Gender [f/m]	11/9	12/14	12/10	15/1	13/6	10/2
Age (y)	4.8 (0.8)	4.9 (0.8)	5.0 (0.7)	83.9 (8.2)	80.1 (6.5)	81.4 (6.4)
Height (cm)	110.0 (6.4)	113.0 (6.5)	113.0 (5.1)	158.0 (5.8)	165.0 (8.3)	160.5 (6.6)
Weight (kg)	18.9 (2.7)	19.8 (2.5)	20.7 (3.8)	63.5 (4.9)	75.2 (14.2)	71.7 (11.1)
BMI (kg/m^2)	15.6 (1.2)	15.5 (0.7)	16.0 (1.7)	25.5 (4.9)	27.6 (4.2)	27.7 (3.3)

Notes.
Data are reported as means with standard deviation (SD).
IG, intergenerational group; PG, peer group; CON, control group; f, female; m, male; BMI, body mass index.

Table 2 Physical performance parameters of children.

		Pre Mean (SD)	Post Mean (SD)	Mean Difference (95% CI)		Cohen's *d* [95% CI]	
Jump height (cm)	IG	13.2 (4.1)	16.6 (3.0)	3.47	[2.03; 4.79]	0.97	[0.49; 1.45]
	PG	14.6 (4.5)	16.6 (3.1)	2.02	[0.50; 3.77]	0.53	[0.10; 0.96]
	CON	14.3 (4.3)	15.5 (3.5)	1.19	[−2.49; 2.83]	0.23	[−0.42; 0.72]
Maximum Jump Power (W/kg)	IG	23.4 (3.9)	29.4 (4.7)	5.96	[3.65; 8.56]	1.38	[0.57; 2.04]
	PG	27.5 (5.4)	30.2 (4.2)	2.73	[1.10; 4.57]	0.57	[0.18; 0.98]
	CON	25.9 (4.8)	30.2 (3.9)	4.29	[3.05; 6.01]	0.98	[0.61; 1.46]
Handgrip strength (N)	IG	76.9 (16.0)	95.5 (19.2)	18.20	[13.60; 24.10]	1.03	[0.76; 1.28]
	PG	83.3 (21.9)	88.2 (21.9)	4.44	[−0.80; 10.40]	0.20	[−0.06; 0.46]
	CON	80.7 (17.6)	78.7 (23.3)	−2.46	[−8.99; 1.95]	−0.12	[−0.42; 0.11]
Rate of force development (N/s)	IG	25.6 (14.8)	36.9 (10.1)	10.90	[3.76; 16.50]	0.86	[0.09; 1.46]
	PG	34.7 (16.2)	38.1 (17.7)	2.91	[−0.62; 6.43]	0.17	[−0.05; 0.39]
	CON	28.1 (14.8)	24.6 (14.8)	−4.06	[−9.30; 0.56]	−0.27	[−0.57; 0.11]
Locomotor skills	IG	32.6 (11.0)	40.9 (9.2)	8.30	[4.80; 11.20]	0.82	[0.42; 1.29]
	PG	34.5 (7.0)	36.3 (6.1)	1.85	[−1.08; 4.69]	0.28	[−0.18; 0.77]
	CON	29.6 (10.1)	32.0 (7.6)	2.45	[−1.43; 6.55]	0.27	[−0.18; 0.76]
Object control skills	IG	15.2 (5.9)	21.1 (5.9)	5.90	[3.70; 8.25]	1.00	[0.49; 1.60]
	PG	15.0 (7.3)	19.2 (6.8)	4.19	[1.88; 6.42]	0.60	[0.26; 0.98]
	CON	18.2 (6.6)	19.6 (6.5)	1.41	[−1.68; 4.09]	0.22	[−0.27; 0.70]
TGMD-2 total score	IG	47.8 (14.1)	62.0 (14.2)	13.90	[9.71; 17.40]	1.00	[0.57; 1.55]
	PG	49.5 (12.0)	55.5 (10.9)	6.04	[1.65; 10.20]	0.53	[0.12; 0.94]
	CON	47.8 (14.4)	51.7 (12.7)	3.86	[−0.55; 9.32]	0.32	[−0.06; 0.69]

Notes.
Data are reported as mean with standard deviation (SD). Mean differences calculated for each group with corresponding effect sizes and 95% confidence intervals [95% CI].
TGMD-2, Test of Gross Motor Skills 2.

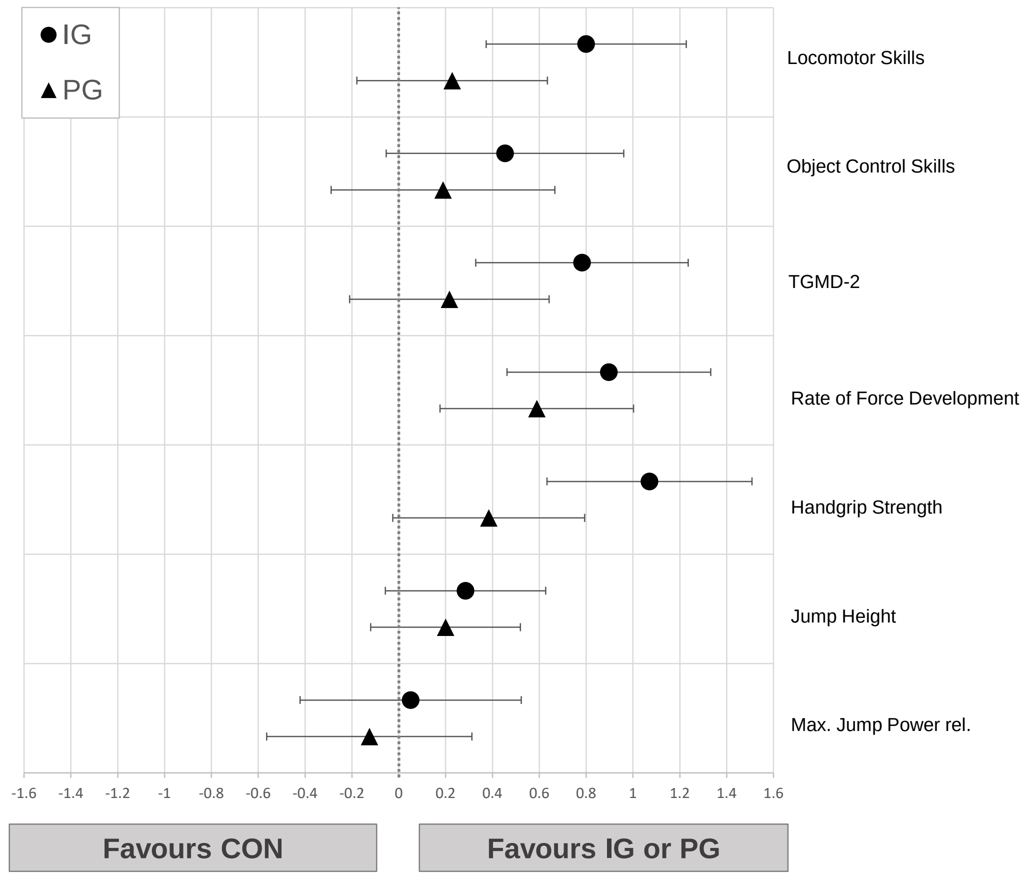

Figure 2 **Effects of the intergenerational (IG) and peer groups (PG) on physical performance parameters in children compared to control condition (CON), corrected for baseline values and age.** Data are presented as mean between-group differences with 95% confidence intervals.

Full-size DOI: 10.7717/peerj.11292/fig-2

Social-emotional skills

Pre-post comparison showed small to moderate improvements in IG ($0.36<d \leq 0.71$) and CON ($0.38<d \leq 0.72$) while PG showed only trivial effects ($-0.09<d \leq 0.12$) in all social-emotional dimensions (Table 3). The linear regression models showed no relevant differences when comparing IG to CON ($-0.12<d \leq 0.14$). PG was slightly inferior to CON in psychological wellbeing ($d = -0.38$ [-0.71; -0.05]) and total KOMPIK score ($d = -0.31$ [-0.54; -0.08]) (Fig. 3).

Seniors

Physical performance

Changes from pre- to post-test in physical performance parameters of seniors from all groups are shown in Table 4. We observed small to large decreases in all measured parameters in CON ($-0.90<d\leq$-0.36) while IG improved all physical performance variables ($0.33<d \leq 1.07$) and PG improved all scores ($0.62<d \leq 1.10$) except gait ($-0.23<d \leq 0.06$). Linear regressions showed moderate to very large improvements in IG ($0.76<d \leq 2.53$) and small to very large effects in PG ($0.26<d \leq 2.10$) compared to CON in all parameters.

Table 3 Social-emotional skills of children.

		Pre Mean (SD)	Post Mean (SD)	Mean Difference [95% CI]		Cohen's *d* [95% CI]	
Social Skills	**IG**	45.5 (16.7)	54.9 (8.8)	9.40	[5.85; 14.60]	0.71	[0.48; 1.01]
	PG	56.5 (10.3)	57.7 (9.3)	1.15	[−1.00; 3.62]	0.12	[−0.11; 0.41]
	CON	53.2 (6.6)	57.6 (8.3)	4.41	[1.86; 6.68]	0.59	[0.21; 1.00]
Emotional Skills	**IG**	34.6 (10.0)	40.1 (5.2)	5.45	[2.70; 8.70]	0.69	[0.37; 1.08]
	PG	41.8 (5.3)	41.3 (7.5)	−0.58	[−2.15; 2.23]	−0.09	[−0.36; 0.35]
	CON	40.7 (3.8)	42.4 (5.1)	1.73	[−0.05; 3.41]	0.38	[−0.01; 0.84]
Psychological Well-being and Social Relationships	**IG**	39.8 (8.8)	43.0 (9.1)	3.20	[0.55; 5.50]	0.36	[0.01; 0.68]
	PG	47.0 (7.4)	47.4 (8.4)	0.46	[−0.96; 2.00]	0.05	[−0.11; 0.30]
	CON	44.7 (4.9)	48.2 (5.0)	3.55	[2.00; 4.95]	0.72	[0.34; 1.12]
KOMPIK Total Score	**IG**	119.9 (34.0)	138.0 (19.5)	18.10	[11.20; 25.90]	0.65	[0.45; 0.92]
	PG	145.3 (21.3)	146.4 (22.0)	1.04	[−2.54; 5.27]	0.05	[−0.12; 0.27]
	CON	138.6 (12.5)	148.2 (15.5)	9.68	[5.32; 13.60]	0.69	[0.37; 1.04]

Notes.
Data are reported as mean with standard deviation (SD). Mean differences calculated for each group with corresponding effect sizes and 95% confidence intervals [95% CI].

Regarding differences between IG and PG, the confidence intervals of the effect sizes implicate a compatibility of the data with trivial to at least medium differences in favor of IG for SPPB and for both gait conditions, while trivial to medium effects can be observed for PG in maximum power of CRT (Fig. 4).

Cardiovascular health

Changes from pre- to post-test in cardiovascular parameters of seniors from all groups are shown in Table 4. IG showed decreases of central systolic and diastolic blood pressure while PG showed more favorable effects in lowering AIx@75. Confidence intervals of the linear regressions implicate small differences in favor of IG compared to CON in PWV (d = 0.47 [0.10;0.84]). Trivial to small differences between IG and PG in cardiovascular health parameters were observed (Fig. 4).

Psychosocial wellbeing and quality of life

Changes from pre- to post-test in psychosocial wellbeing of all groups are shown in Table 5. IG seniors showed small improvements throughout all dimensions of the SF-36 questionnaires ($0.31 < d \leq 0.38$) while PG showed trivial changes ($-0.17 < d \leq 0.05$) and CON revealed moderate decreases in physical ($d = -0.57$) and mental health ($d = -0.57$) (see Table 5). In the AQoL, IG recorded small to moderate improvements in total score (d = 0.42), mental health (d = 0.53), self-worth (d = 0.68) and relationships (d = 0.22). PG showed trivial to small decreases ($-0.45 < d \leq$-0.03) while CON revealed small to moderate ($-0.77 < d \leq 0.17$) declines in all dimensions. Fear of falling (FES) increased in PG ($d = -0.36$) and CON ($d = -0.50$) while it remained the same in IG (d = 0.09). Small to large differences in favor of IG compared to CON are compatible with the data in total SF-36 score (d = 0.94 [0.28;1.59]), physical health (d = 1.05 [0.33;0.38]), AQoL total score (d = 1.20 [0.61;1.79]), pain (d =0.92 [0.36;1.48]), relationships (d = 1.70 [0.95;2.45]) as

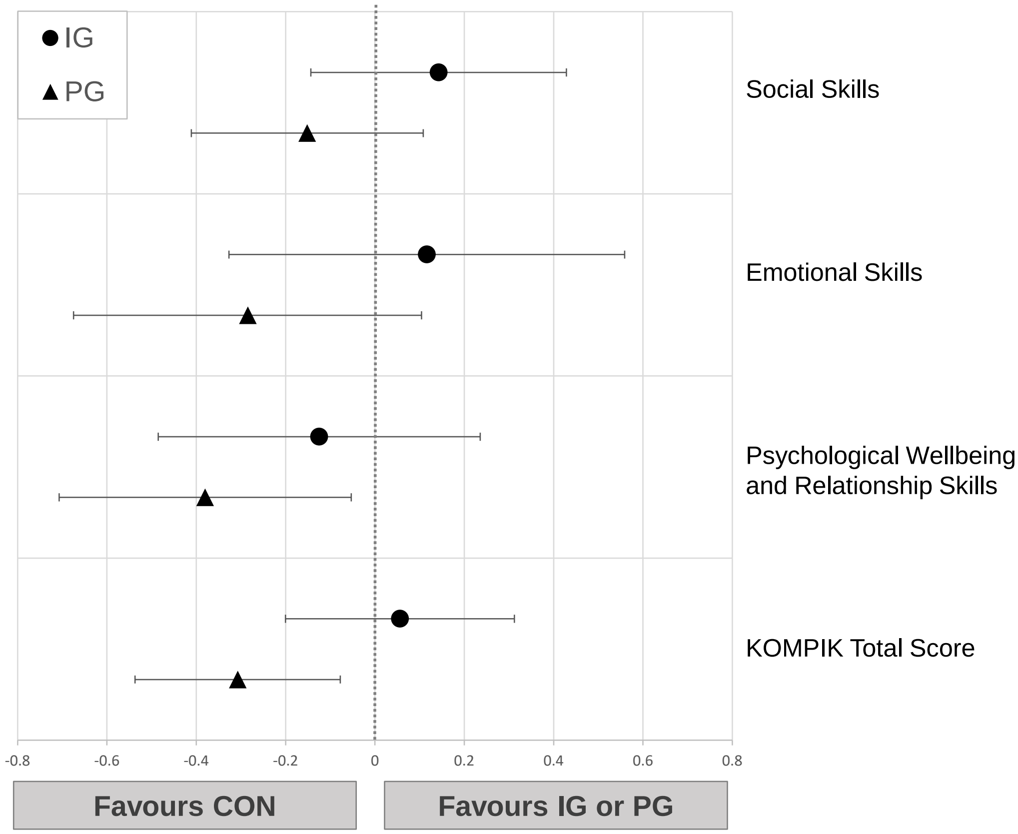

Figure 3 Effects of the intergenerational (IG) and peer groups (PG) on social-emotional skills in children compared to control condition (CON), corrected for baseline values and age. Data are presented as mean between-group differences with 95% confidence intervals.

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well as FES score ($d = 0.89$ [0.21;1.58]). Comparing IG to PG, the observed effects in favor of IG are trivial to small (Fig. 5).

DISCUSSION

This study examined the effects of an intergenerational exercise training program on physical as well as psychosocial health parameters of preschool children and residential seniors compared to peer group training and inactive control groups. Our results show that both generations, preschool children as well as seniors living in a home for the elderly, can benefit from an intergenerational exercise setting, both on a physical as well as on a psychosocial level. Not only was the intergenerational setting superior to control conditions, the results show that intergenerational exercise is comparable and in certain dimensions superior to peer group exercise.

Effects in children

Our results show improvements in physical performance in all three groups of children. As childhood is dominated by various biological processes which affect the neuromuscular

Table 4 Physical performance and cardiovascular health parameters of seniors.

		Pre Mean (SD)	Post Mean (SD)	Mean Difference [95% CI]		Cohen's *d* [95% CI]	
SPPB Total	IG	6.3 (2.1)	8.0 (2.4)	2.56	[1.69; 3.31]	1.07	[0.61; 1.63]
	PG	8.3 (1.1)	9.5 (1.1)	1.32	[0.68; 1.95]	1.10	[0.50; 1.73]
	CON	7.8 (2.1)	4.8 (4.0)	−3.0	[−4.42; −1.75]	−0.96	[−1.72; −0.49]
Rel. Pmax CRT (W/kg)	IG	4.6 (1.5)	5.0 (1.3)	0.45	[0.09; 0.99]	0.33	[0.04; 0.79]
	PG	6.2 (1.2)	7.0 (1.3)	0.79	[0.35; 1.20]	0.62	[0.23; 0.98]
	CON	4.8 (1.1)	4.0 (1.3)	−0.75	[−1.30; −0.33]	−0.66	[−1.26; −0.26]
CRT time (s)	IG	19.2 (6.7)	14.4 (8.9)	−4.82	[−8.77; −1.33]	0.61	[−0.04; 1.24]
	PG	17.1 (3.5)	13.6 (3.2)	−3.51	[−5.05; −2.33]	1.05	[0.62; 1.60]
	CON	17.8 (4.1)	23.4 (9.9)	4.92	[1.97; 9.92]	−0.65	[−1.13; −0.33]
Gait speed single task (m/s)	IG	0.69 (0.25)	0.88 (0.27)	0.19	[0.12; 0.27]	0.72	[0.42; 1.14]
	PG	1.16 (0.24)	1.18 (0.25)	0.01	[−0.04; 0.06]	0.06	[−0.19; 0.26]
	CON	0.79 (0.31)	0.68 (0.31)	−0.11	[−0.20; −0.06]	−0.36	[−0.77; −0.16]
Gait speed dual task (m/s)	IG	0.60 (0.26)	0.72 (0.27)	0.13	[0.07; 0.22]	0.49	[0.18; 0.82]
	PG	1.05 (0.26)	0.98 (0.33)	−0.07	[−0.16; 0.01]	−0.23	[−0.58; 0.05]
	CON	0.73 (0.30)	0.59 (0.31)	−0.14	[−0.27; −0.05]	−0.46	[−1.09; −0.17]
cSBP (mmHg)	IG	123 (14)	115 (15)	−8.47	[−16.1; −3.06]	0.58	[0.17; 1.10]
	PG	128 (17)	127 (12)	−1.89	[−9.55; 4.92]	0.13	[0.40; 0.66]
	CON	122 (24)	126 (17)	3.10	[−17.10;15.9]	−0.15	[−1.00; 0.75]
cDBP (mmHg)	IG	83 (11)	77 (11)	−6.47	[−11.90; −2.34]	0.58	[0.11; 1.16]
	PG	83 (7)	83 (10)	0.26	[−3.32; 4.11]	−0.03	[−0.51; 0.41]
	CON	78 (8)	78 (9)	−0.42	[−6.99; 5.08]	0.05	[−0.73; 0.84]
AIx@75 (%)	IG	31.3 (9.1)	32.6 (11.8)	1.28	[−3.47; 5.03]	−0.12	[−0.55; 0.34]
	PG	31.3 (11.8)	25.7 (11.9)	−5.63	[−11.70; −0.82]	0.48	[0.05; 1.00]
	CON	28.5 (10.6)	35.6 (7.4)	7.15	[0.90; 13.60]	−0.78	[−1.57; 0.07]
PWV (m/s)	IG	13.1 (2.1)	13.0 (1.9)	−0.11	[−0.35; 0.08]	0.06	[−0.06; 0.16]
	PG	12.5 (1.7)	12.5 (1.4)	−0.02	[−0.35; 0.28]	0.11	[−0.2; 0.26]
	CON	12.6 (1.6)	13.3 (1.7)	0.78	[−0.05; 1.73]	−0.48	[−1.02; 0.09]

Notes.

Data are reported as mean with standard deviation (SD). Mean differences calculated for each group with corresponding effect sizes and 95% confidence intervals [95% CI]. SPPB, Short Physical Performance Battery; CRT, Repeated Chair Rising Test; cSBP, central systolic blood pressure; cDBP, central diastolic blood pressure; AIx@75, augmentation index corrected for 75 heartbeats per minute; PWV, pulse wave velocity.

as well as cognitive development (*Beunen , 2000*), improvements during the half-year period independently of the intervention were expected. Our data provides two important insights: First, we were able to show that exercise positively influences physical development and should be seen as a crucial element of healthy childhood. Secondly, intergenerational exercise is promising and should be considered as a complementary approach to promote motor development in preschoolers. Compared to both CON and PG, children in IG profit more especially with respect to motor skill development. As studies have shown a strong link between motor skill proficiency and overall long-term physical and cardiovascular fitness (*Vlahov, Baghurst & Mwavita, 2014*), this finding is of high importance in providing children with a strong foundation for lifelong health. We cannot explain the underlying causes for this development as it was not the scope of our study and

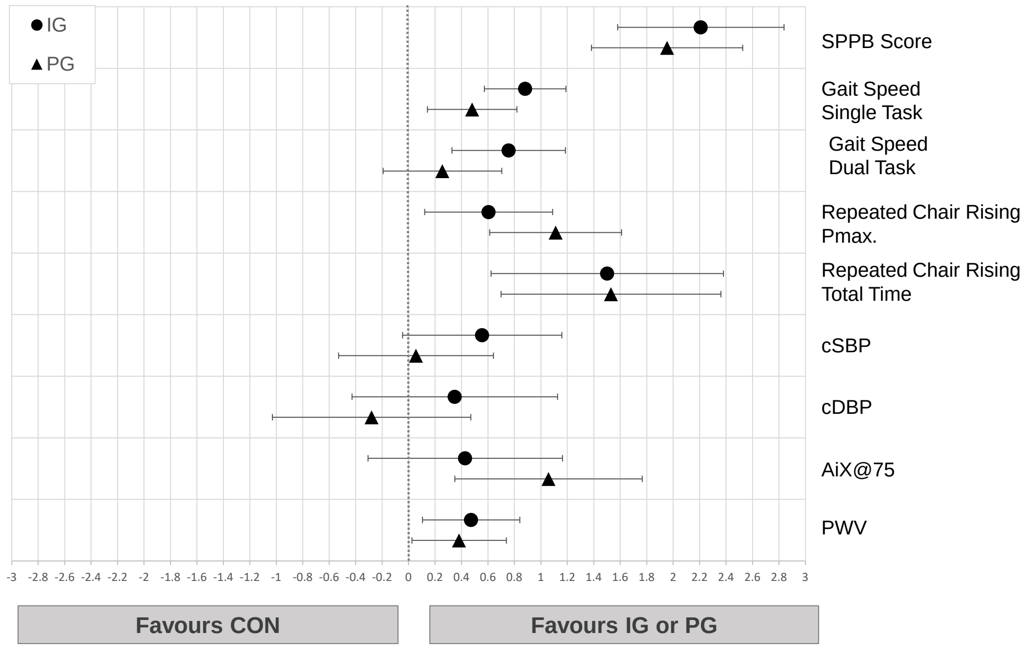

Figure 4 Effects of the intergenerational (IG) and peer groups (PG) on physical performance and cardiovascular health in seniors compared to control condition (CON), corrected for baseline values and age. Data are presented as mean between-group differences with 95% confidence intervals.
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should be examined in further research. Nonetheless, certain assumptions can be made. In the intergenerational setting, children were paired with seniors for group activities and exercises. As a consequence, the children had to adapt to their partners in a more distinctive manner than when playing with peers. Seniors move more slowly than children, have longer reaction times and might have certain physical limitations which affect how the children need to interact with them. In order to keep a game ongoing, children might have been compelled to move themselves as well as objects in a more controlled and precise manner, therefore increasing awareness of their movements and demanding better body control. Additionally to the nature of their movement patterns, they might have been in constant motion in order to keep the games ongoing, thus being under a constant, albeit low, load. All groups improved social skills, psychological wellbeing and the ability to build and maintain social relationships. This attests to the notion that childhood is crucial for social-emotional development (*Denham et al., 2014*). Our data does not allow an interpretation clearly favoring the intergenerational setting. We cannot distinguish whether this is due to the complex nature and synergies which influence social-emotional learning or if the duration and exposure of the intervention was not long enough. The intergenerational setting provides children with many challenges for their social-emotional profile, which do not show short-term effect but might have consequences for the children at a later stage of life. Long-term studies examining this setting are necessary in order to make further statements.

Table 5 Psychosocial wellbeing and quality of life of seniors.

		Pre Mean (SD)	Post Mean (SD)	Mean Difference [95% CI]		Cohen's *d* [95% CI]	
SF-36							
Total Score	**IG**	70.5 (20.3)	77.1 (14.6)	6.62	[0.72; 12.80]	0.38	[0.01; 0.71]
	PG	78.8 (10.3)	79.4 (14.1)	0.60	[−5.88; 6.88]	0.05	[−0.46; 0.64]
	CON	79.5 (12.4)	69.3 (19.9)	−10.20	[−19.50; −4.94]	−0.62	[−1.01; −0.23]
Physical Health	**IG**	66.7 (22.4)	74.5 (18.7)	7.77	[0.82; 14.10]	0.37	[0.02; 0.72]
	PG	77.4 (12.4)	76.7 (17.0)	−1.15	[−9.13; 5.38]	−0.08	[−0.56; 0.44]
	CON	73.3 (15.0)	61.8 (24.1)	−11.5	[−20.60; −3.70]	−0.57	[−1.07; −0.12]
Mental Health	**IG**	74.3 (21.2)	79.8 (13.0)	5.47	[−0.97; 14.20]	0.31	[−0.10; 0.77]
	PG	84.3 (11.1)	82.2 (12.9)	−2.03	[−6.32; 4.61]	−0.17	[−0.55; 0.44]
	CON	85.7 (11.6)	76.9 (18.7)	−8.85	[−18.10; −1.54]	−0.57	[−1.05; −0.01]
AQoL-8D							
Total Score	**IG**	64.8 (13.3)	59.8 (10.9)	−5.06	[−8.12; −1.94]	0.42	[0.14; 0.82]
	PG	55.9 (10.2)	58.4 (12.5)	2.42	[−0.95; 7.11]	−0.21	[−0.55; 0.12]
	CON	62.8 (16.3)	73.8 (23.8)	11.00	[5.50; 22.30]	−0.54	[−0.88; −0.30]
Independent Living	**IG**	9.4 (2.5)	9.0 (3.5)	−0.44	[−1.38; 0.44]	0.14	[−0.18; 0.52]
	PG	6.1 (1.8)	6.7 (2.5)	0.63	[−0.11; 1.42]	−0.30	[−0.64; 0.07]
	CON	10.0 (3.4)	10.0 (3.4)	1.58	[−1.25; 3.83]	−0.41	[−1.62; 0.42]
Pain	**IG**	4.9 (2.1)	4.9 (2.1)	0.00	[−0.56; 0.81]	0.00	[−0.32; 0.44]
	PG	5.3 (2.1)	5.7 (2.0)	0.42	[−0.32; 1.11]	−0.21	[−0.57; 0.17]
	CON	6.3 (2.8)	8.0 (3.1)	1.67	[0.50; 2.67]	−0.56	[−1.16; −0.16]
Mental Health	**IG**	17.3 (4.6)	15.1 (3.2)	−2.25	[−3.12; −1.44]	0.53	[0.31; 0.78]
	PG	15.2 (3.2)	15.6 (3.2)	0.42	[−0.90; 1.53]	−0.13	[−0.48; 0.35]
	CON	14.3 (3.7)	14.7 (6.4)	1.67	[0.25; 3.58]	−0.39	[−0.80; 0.00]
Life satisfaction	**IG**	8.9 (2.1)	8.6 (2.4)	−0.38	[−1.00; 0.19]	0.17	[−1.33; 0.53]
	PG	7.3 (1.3)	8.0 (1.7)	0.68	[−0.05; 1.63]	−0.45	[−0.97; 0.04]
	CON	9.3 (3.0)	9.9 (4.0)	0.58	[−0.75; 2.00]	0.17	[−0.53; 0.29]
Self-worth	**IG**	6.1 (2.0)	4.9 (1.4)	−1.19	[−1.88; −0.69]	0.68	[0.32; 1.16]
	PG	5.2 (1.4)	5.2 (1.8)	0.05	[−0.95; 0.95]	−0.03	[−0.34; 0.67]
	CON	5.4 (2.5)	6.1 (3.1)	0.67	[−0.42; 1.92]	−0.24	[−0.70; 0.21]
Coping	**IG**	6.3 (1.7)	6.1 (1.5)	−0.25	[−1.00; 0.38]	0.16	[−0.30; 0.64]
	PG	5.7 (1.1)	6.1 (1.9)	0.37	[−1.21; 0.32]	−0.24	[−0.74; 0.27]
	CON	5.7 (2.3)	7.0 (3.1)	1.33	[0.00; 3.08]	−0.48	[−1.07; 0.04]
Relationships	**IG**	11.8 (2.5)	11.3 (2.5)	−0.56	[−1.44; 0.38]	0.22	[−0.20; 0.62]
	PG	11.1 (2.4)	11.2 (3.0)	0.11	[−0.58; 1.26]	−0.04	[−0.49; 0.23]
	CON	11.8 (3.0)	15.3 (5.7)	3.50	[1.50; 5.50]	−0.77	[−1.37; −0.34]
FES	**IG**	25.1 (7.7)	24.3 (8.5)	−0.75	[−3.56; 1.25]	0.09	[−0.17; 0.51]
	PG	19.3 (3.7)	21.1 (5.9)	1.79	[0.53; 3.84]	−0.36	[−0.64; −0.12]
	CON	27.7 (9.9)	33.4 (12.9)	5.75	[−0.92; 11.80]	−0.50	[−1.03; 0.18]

Notes.

Data are reported as mean with standard deviation (SD). Mean differences calculated for each group with corresponding effect sizes and 95% confidence intervals [95% CI].
SF-36, General Health Questionnaire; AQoL-8D, Assessment of Quality of Life questionnaire, 8 dimensions; FES, Falls Efficacy Scale.

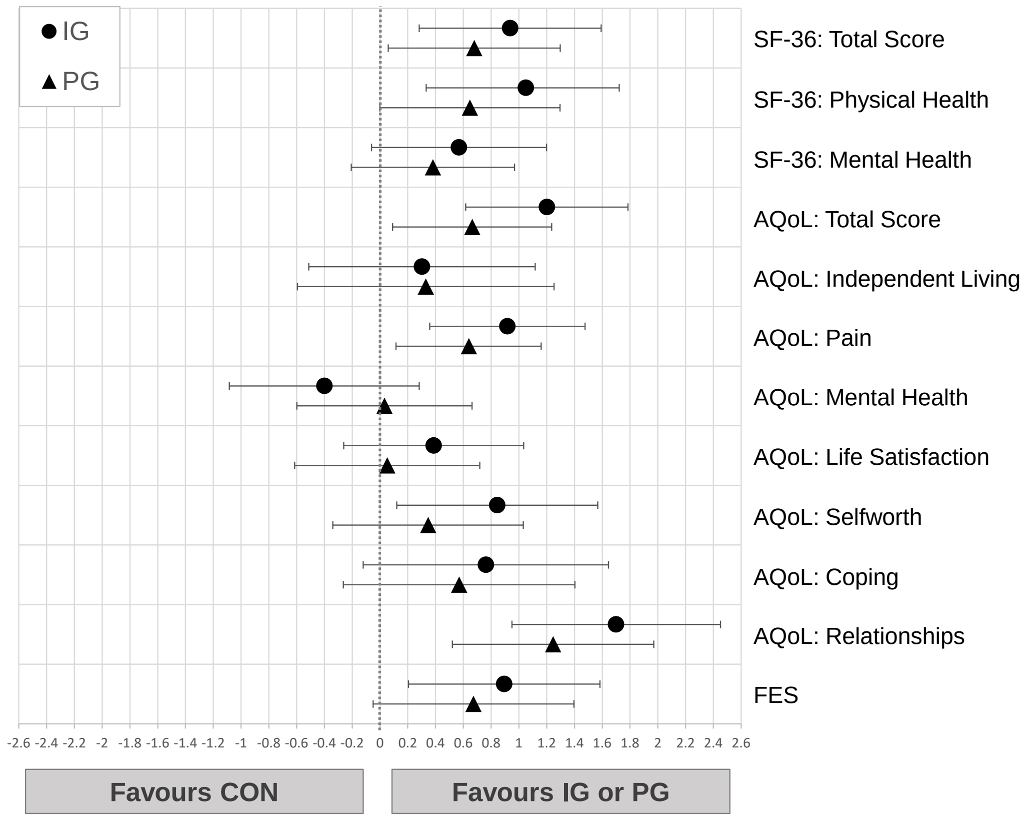

Figure 5 Effects of the intergenerational (IG) and peer groups (PG) on psychosocial wellbeing and quality of life in seniors compared to control condition (CON), corrected for baseline values and age. Data are presented as mean between-group differences with 95% confidence intervals.

Full-size DOI: 10.7717/peerj.11292/fig-5

Effects in seniors

Our physical performance data clearly points towards the importance of regular physical activity in general in older age, especially in residential care settings. Declines in strength, cardiovascular health and functional mobility which occur due to biological aging processes are accelerated by inactivity (*Vandervoort, 2002*), as shown by our control group. In contrast, both intervention groups were able to not only maintain but increase physical health and functionality parameters. The improvements can be considered relevant, especially since they are a population which, due their living situation, has lost their independence to a notable extent. Both gait speed and SPPB scores are used to assess independent living, hospitalization and mortality in elderly populations (*Abellan van Kan et al., 2009*; *Cabrero-Garcia et al., 2012*), and improvements in those scores can have large impacts on individual daily life of such residents by increasing their independence, especially in performing activities of daily life which are based on functional movement patterns. As to the differences between intergenerational and peer groups, one setting does not seem to be superior to the other with regard to physical parameters. Intergenerational seniors improved especially in gait performance and showed lower blood pressure values while seniors in the peer group showed slightly larger gains in maximum power and a larger reduction in arterial stiffness. While both intervention settings benefit, to different degrees, the physical health of seniors, the presence of children has a larger impact on quality of life, perceived mental and physical health as well as on self-worth and relationships of residential seniors. This finding is highly relevant. Studies examining quality of life in elderly institutionalized individuals have shown that quality of life is a complex construct based on internal and external factors. Physical health, social supports and personality traits (*Kane, 2003*) play an important role in how quality of life is perceived. But quality of life also strongly relates to whether a person is recognized as an individual and by doing meaningful things (*Hjaltadottir & Gustafsdottir, 2007*). Our results let us assume that the presence and collaboration with children had a direct and positive impact on various dimensions of that construct. A setting which combines functional motor tasks while focusing on interactions between old and young not only increases physical performance but improves psychosocial wellbeing in residential seniors to a larger extent than peer group exercise.

Methodological considerations

A number of limitations of the study need to be mentioned. Due to the complex setting in kindergartens and senior homes, the participants could not be cluster-randomized in a systematic manner. Nonetheless, it was possible to consider certain criteria when allocating the study arms allowing for balanced baseline data between the age groups. The number of participants per group is relatively small due to the number of study arms and the strict exclusion criteria of senior participants. As this study aimed at examining the effects of a new exercise setting compared to usual exercise settings and control conditions, the number of study arms was necessary and provided valuable information on how to interpret the acquired data. Furthermore, most of our senior participants were female and individuals who enjoy the company of children. Therefore, one must be careful in generalizing and applying the information. Nevertheless, this study reveals important information on two age groups in a field which has not been previously explored and which provides a solid foundation for future studies in the field of intergenerational exercise.

CONCLUSION AND PRACTICAL APPLICATIONS

In light of demographic, social and economic changes and the direct impact on the relationship between generations (*Asheim & Tungodden, 2007*), such extra-familiar intergenerational programs possess great potential for both generations. Children profit from intergenerational exercise primarily in motor skill proficiency while seniors benefit, first and foremost, in psychosocial wellbeing while also improving functional mobility necessary for everyday life. Intergenerational exercise is a promising strategy to promote physical performance parameters in children which are necessary for lifelong physical health and fitness while simultaneously challenging their social-emotional learning skills. For seniors, this exercise setting shows great promise in not only maintaining but also improving physical health and especially in benefitting psychological health and elevating quality of life in homes of the elderly. Our study provides necessary evidence proving that the intergenerational exercise setting satisfies the interests and needs of both generations and is, therefore, mutually beneficial. Therefore, opportunities for such exercise should be facilitated. Future large, randomized studies are warranted in order to confirm or refute the observed effects in the intergenerational groups and examine potential underlying causes.

Abbreviations

AIx@75	augmentation index corrected for 75 heartbeats per minute
AQoL-8D	assessment of quality of life questionnaire
BMI	body mass index
cDBP	central diastolic blood pressure
95% CI	95% confidence intervals
CMJ	counter movement jump
CON	control group
CRT	repeated chair rising test
cSBP	central systolic blood pressure
FES	falls efficacy scale
IG	intergenerational group
MVPA	moderate to vigorous physical activity
PG	peer group
PWV	pulse wave velocity
SD	standard deviation
SF-36	general health questionnaire
SPPB	short physical performance battery
TGMD-2	test of gross motor development, second edition.

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Competing Interests

The authors declare there are no competing interests.

Author Contributions

- Alice Minghetti conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the paper, and approved the final draft.
- Lars Donath, Lukas Zahner and Henner Hanssen conceived and designed the experiments, authored or reviewed drafts of the paper, and approved the final draft.
- Oliver Faude analyzed the data, authored or reviewed drafts of the paper, and approved the final draft.

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Chapter 4
Publication 2

Physical performance, cardiovascular health and psychosocial wellbeing in older adults compared to oldest-old residential seniors

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Article

Physical Performance, Cardiovascular Health and Psychosocial Wellbeing in Older Adults Compared to Oldest-Old Residential Seniors

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Abstract: Background: This study analyzed physical, cardiovascular, and psychosocial health in different age groups at the far end of the lifespan. Methods: Sixty-two residential seniors participated in this cross-sectional study and were assigned according to age to either the older adults (n = 27; age: 74.8 (3.6); f: 23) or the oldest-old group (n = 35; age: 87.2 (5.0); f: 28). Gait speed, functional mobility, handgrip strength, and pulse wave velocity (PWV) were measured. Additionally, questionnaires to assess quality of life were applied. Mean between-group differences (Δ) and Hedge's g with 95 % confidence intervals were calculated. Results: Oldest-old had moderately lower handgrip strength (Δ = −31.3 N, 95% CI [−66.30; −1.65], Hedge's g = 0.49 [−0.97; 0.03]) and relevant lower gait speed than the older adults (Δ = −0.11 m/s [−0.28; 0.05], g = 0.34 [−0.89; 0.20]). All other physical parameters showed trivial differences. Very large effects were found in PWV in favor of the older adults (Δ = −2.65 m/s [−3.26; −2.04], g = −2.14 [−2.81; −1.36]). The questionnaires showed trivial to small differences. Conclusion: We found small differences in physical as well as psychosocial health between age groups with large inter-individual variance. Large differences were found in arterial stiffness, which increases with age. Exercise programs in nursing homes should consider physical, psychosocial, and cardiovascular variables more than age.

Keywords: aging; older adults; nursing homes; quality of life; strength

1. Introduction

As life expectancy of our population increases, the importance of healthy aging and increasing the number of disability-free years becomes all the more relevant. People aged 80 years and older are projected to triple in number within 30 years, representing the most rapidly growing age group [1]. Consequently, the preservation of health and physical and psychosocial function in the oldest-old will become a crucial challenge for the healthcare system and general public. Switzerland spends more than 10.4 billion Swiss francs on nursing homes or home-based care per year, tending for more than 150,000 seniors in these settings [2]. To design adequate and tailored interventions to the specific and individual needs of residential seniors, potential differences concerning various bodily systems between the age groups at the far end of the lifespan have to be examined and understood.

On a neuromuscular level, the biological aging process negatively affects motor function and sensory systems [3,4]. Motor units undergo a process of reduction and adaptation due to progressive motoneuron death and fiber denervation [5]. This degenerative process negatively influences the capacity to produce force adequately. From the sixth decade onward, the loss of lean muscle mass and, more pronounced, muscular strength is substantial: in healthy adults in their seventh and eighth decade of life, this can result in a 20–40% loss of isometric strength compared to young adults in their thirties and forties. In the ninth decade, it can lead up to a 50% loss [3,6]. Such substantial declines in physical performance not only negatively impact functional ability and, in turn, daily life and independent living, but also lead to a high risk of falling [7]. The risk of sustaining a fall increases with age: while in Switzerland seniors between 65 and 79 years of age are at a 25% risk of falling in the course of a year, the number rises to 33% in octogenarians [8]. Furthermore, falls in the elderly are directly linked to declines in functionality, institutionalization, and mortality [9].

Apart from neuromuscular deteriorations, prominent changes due to aging and inactivity occur in the structural and mechanical properties of the vascular system, resulting in increased arterial stiffening [10]. The stiffening and dilatation of large arteries is a degeneration of the arterial wall. This process is detectable by an increased pulse wave velocity (PWV) and the development of systolic hypertension [11]. About 50% of people aged 60 years and older are affected by hypertension and, in general, cardiovascular disease remains the leading cause of death worldwide [12].

These biological aging processes have a negative impact also on psychosocial wellbeing and therefore quality of life. Impairments and limitations in one's functional mobility are not only correlated to mortality and institutionalization [13], but also to the reduction of social activities and interactions and a decreased quality of life [7]. Quality of life, therefore, is strongly dependent on physical functioning. Studies were able to show lower health-related quality of life in nursing home residents than in seniors living at home, which is mainly caused by lower physical activity levels in nursing homes [14]. Physical autonomy is of utmost importance in old age if one wishes to live in a healthy and fulfilling mental state.

From a public health perspective, understanding the health status and functionality at the far end of a lifespan might be necessary in order to tailor specific health promotion programs to support high quality of life in old age, especially in residential care. Most available information on physical and psychosocial health comes from seniors between 60 and 80 years of age, omitting older individuals. Few studies have provided insight into the oldest-old (≥81 years old) [5], and reference values for physical performance parameters in these late stages of life are therefore largely lacking. These age groups nevertheless are of special interest since the few existing studies have shown that the decline in functionality accelerates in the ninth decade of life [5,13,15]. Our study therefore examined functional mobility, cardiovascular health, and psychosocial wellbeing in residential seniors, comparing the older adults (≤80 years old) with the oldest-old (≥81 years old). We additionally examined whether there were any associations between outcome parameters in the different health domains and compared our data to available reference values.

2. Methods

2.1. Study Design and Study Population

We asked all nursing homes and senior living facilities in the city of Basel-Stadt to participate, and included all homes which were interested. In total, five senior residences in the canton Basel-Stadt, Switzerland, including 62 seniors (age: 81.2 (7.6) years; f: 51) participated in this cross-sectional study. Seniors living in the participating facilities of at least 65 years of age were included. Excluded were seniors suffering from one or more of the following illnesses: chronic and/or congenital heart failure, peripheral neuropathy, peripheral arterial occlusive diseases, diabetes mellitus or a diagnosis of cognitive illness such as Alzheimer's disease or dementia. Participants were recruited and screened by medical staff in the respective nursing homes. For the present analysis, we divided the enrolled participants into two age groups: either the older adults (≤80 years old) or the oldest-old (≥81 years old) group [5]. The study was approved by the local ethics committee (Ethikkommission Nordwest- und Zentralschweiz, ethical approval number: 2018-01123) and all participants signed a written informed consent after having been informed about the study.

2.2. Procedures

We conducted all measurements in the respective nursing homes. A team of experienced assessors adhering to standard operation procedures conducted the tests. Nursing home staff was included in the test standardization for the questionnaires. We performed all measurements in the morning and the patients were asked to refrain from physical exercise, eating, as well as drinking caffeine or alcohol 12 h prior to testing, as these factors can influence cardiovascular measurements. We collected anthropometric data (weight and height) prior to the physical and cardiovascular tests to calculate body mass index (BMI).

2.3. Short Physical Performance Battery

We assessed functional mobility using the three subtests from the Short Physical Performance Battery (SPPB), a reliable and validated protocol to objectively measure lower extremity physical performance and identify older individuals at risk of poor lower-body function. The SPPB is highly predictive for disability, hospitalization, institutionalization, and mortality in community-dwelling elders, with lower scores indicating higher levels of disability [16,17]. The sub-tests consist of usual walking speed over 4 m, the five repetition chair rising test, and three individual balance tests. Participants did not use walking aids such as canes, walking frames, or another person for support in any of the tests.

For gait speed, we recorded the average velocity over 10 m with timing gates (Witty System) in a single- as well as dual-task situation. We used the 4 m split time for the SPPB score analysis. Participants started 1 m before the gate and walked in their habitual speed (i.e., "as if you were walking down the street to walk to a store") to 1 m after the last timing gate. During dual-task, seniors counted backwards out loud starting from 50 in the first and from 70 in the second walk over the same distance. Participants performed each test twice and we used the faster time for analysis. If one person was not able to walk the 4 m distance, this person received 0 points. Scores between 1 and 4 were assigned to the time needed to walk 4 m (1 point: >8.7 s.; 2 points: 6.21–8.7 s.; 3 points: 4.82–6.20 s.; 4 points: ≤4.81 s.) [16].

Participants performed the repeated chair rising test on a force plate (Leonardo Mechanography® GRFP LT, Pforzheim, Germany) with a 46 cm high, locked bench. Participants were asked to fully stand up and sit back down as fast as possible for a total of five repetitions. Participants were thereby not allowed to push off the bench with their hands. The force plate records time per repetition as well maximal power during every stand-to-sit cycle. Total time for the completion of all five stand-to-sit cycles as well as the relative peak power (W/kg) were calculated using raw data exports. Inability to complete all five repetitions, or requiring more than 60 s resulted in 0 points. Points between 1 and 4 were attributed accordingly: 1 point: >16.7 s.; 2 points: 13.7–16.69 s.; 3 points: 11.2–13.69 s.; 4 points: ≤11.19 s. [16].

For the balance assessment, three different stances had to be performed for a total of 10 s: (a) side-by-side stance, with feet placed in a hip-wide distance; (b) semi-tandem stance where one foot of choice was placed with the side of the heel touching the big toe of the other foot, and; (c) tandem stance, where the heel of one foot was placed in front of and touching the toes of the other foot. If participants were not able to hold the stance for 10 s, or if they did not attempt the stance, they received 0 points. Holding the side-by-side and semi-tandem stance for the entire duration was scored with 1 point each. Holding the tandem stance for 10 s was attributed with 2 points, holding the stance for 3 to 9.99 s with 1 point, and less than 3 s or not at all with 0 points [16].

2.4. Handgrip Strength

We assessed handgrip strength using the Leonardo Mechanography GF® (Novotec Medical GmbH, Pforzheim, Germany). Cut-off points predictive for survival analysis are available [18]. Participants were asked to hold their dominant hand in a 90-degree angle and to squeeze the sensor as hard as possible for 5 s. Participants performed two valid measurements with 1 min rest in between. Measurements were counted as invalid if the participants used both hands, lost their grip, or stopped squeezing the device during the 5 s. We extracted peak strength in N from raw data and used the mean of two valid measurements for statistical analysis.

2.5. Cardiovascular Health

The measurement of arterial stiffness parameters using the oscillometric method has been validated [19] and is in good agreement with the conventional tonometric method [20]. Markers of central hemodynamics (central systolic and diastolic blood pressure), augmentation index corrected for 75 bpm (AIx@75) and carotid–femoral pulse wave velocity (PWV) were obtained using a Mobil-O-Graph® PWA Monitor device (I.E.M. GmbH, Stoberg, Germany) with integrated ARCSolver® software. We placed the blood pressure cuff on the left upper arm while the patient was in a seated position after a 10 min resting period. Participants undertook all measurements in a fasting state. We asked them to refrain from physical exercise, eating, as well as drinking caffeine or alcohol 12 h prior to measurement. Twenty-three patients (37%) took antihypertensive medication. These patients refrained from taking this medication the day prior to and of the measurement. We used the mean of three valid measurements for data analysis.

2.6. Questionnaires

Participants filled out three questionnaires with the help of the local nursing staff. Nursing staff read the questions and the possible answers, and asked participants to choose the most appropriate one. As all questionnaires provide examples and reflect situations of daily life, the study participants had no difficulty understanding the questions or giving accurate responses.

The General Health Questionnaire (SF-36) is a validated and reliable questionnaire consisting of eight categories yielding a summary on physical as well as mental health [21]. The physical health includes four scales (General Health, Physical Functioning, Physical Limitations, Bodily Pain) and a total of 21 items. The mental health dimension is composed of four scales (Emotional Limitations, Vitality, Mental Health, Social Functioning) and 14 items. A higher score in all scales represents higher general health.

The Assessment of Quality of Life (AQoL-8D) is a reliable and valid questionnaire to assess quality of life [22], especially in seniors due to its high sensitivity to particular dimensions of physical and psycho-social health. The questionnaire examines the following dimensions in a total of 35 items, all of which are independently representative for the individual dimension of health: independent living, pain, mental health, life satisfaction, coping, relationships, self-worth, and senses. We did not integrate the "senses" dimension in the applied questionnaire as assessment of sensory system and disease status was not an aim of our study. The lower the sum in all dimensions, the better is the psycho-social state of an individual.

The Falls Efficacy Scale (FES) consists of 16 questions and is a widely accepted and applied tool to assess individual concern about falling in the elderly, with excellent reliability and validity [23]. The higher the score (range: 16–64), the more severe is the subjective concern of falling.

2.7. Statistical Analysis

We present the data for both groups as means with standard deviations (SD). We calculated independent *t*-Tests for mean between-group differences (Δ) and Hedge's *g* with 95% confidence intervals. We estimated confidence intervals by bootstrapping with 5000 re-samples. We interpret the P values as a continuous measure of compatibility of the data with the statistical model and not relative to an arbitrary significance threshold [24]. Hedge's *g* is a variation of Cohen's *d* that corrects for biases due to small sample sizes. Effect sizes were interpreted as trivial ($g < 0.2$) small ($0.2 \le g < 0.5$), moderate ($0.5 \le g < 0.8$) and large ($g \ge 0.8$) effects [25]. We performed these analyses by means of estimation-stats.com [26]. Additionally, we calculated Pearson's correlation analysis with 95% confidence intervals to measure the association between two variables whereby the correlation coefficient was interpreted as small ($0.10 \le r \ge 0.29$), moderate ($0.30 \le r \ge 0.49$), large ($0.50 \le r \ge 0.69$), very large ($0.70 \le r \ge 0.89$), and extremely large ($r \ge 0.90$) [27]. We calculated the correlations by means of the jamoviStats software.

3. Results

3.1. Study Population

Twenty-seven individuals belonged to the older adult group (age: 74.8 (3.6) years; BMI: 27.2 (3.6) kg/m^2; female: 23) and 35 to the oldest-old group (age: 87.2 (5.0) years; BMI: 26.6 (4.7) kg/m^2; female: 28).

3.2. Physical Functioning

Handgrip strength was higher in the older adults compared to the oldest-old (Δ = 31.3 N [1.7; 66.3], g = 0.49 [−0.03; 0.97]) with both age groups being on average slightly above risk threshold (216 N) [18]. We observed a small, but on average clinically relevant difference in single- as well as dual-task gait speeds in favor of the older adults ($0.34 < g < 0.37$). However, trivial as well as large effects were also compatible with the data (Figure A1). Effect sizes for between-group differences in all other physical functioning parameters ranged from trivial to small ($0.11 < g < 0.37$) with wide confidence intervals (Table 1).

Table 1. Results for the older adults and oldest-old groups in all parameters.

	Older Adults	Oldest-Old	*t*-Test			
	Mean (SD)	Mean (SD)	Mean Difference [95% CI]		Hedge's g [95% CI]	
SPPB Gait Score	3.3 (1.0)	3.4 (0.9)	0.10	[−0.35; 0.59]	0.11	[−0.40; 0.63]
SPPB CRT Score	1.7 (1.1)	1.5 (0.9)	−0.25	[−0.76; 0.23]	−0.25	[−0.75; 0.26]
SPPB Balance Score	2.9 (1.3)	2.7 (1.1)	−0.24	[−0.82; 0.40]	−0.20	[−0.73; 0.32]
SPPB Total Score	7.9 (2.6)	7.5 (2.1)	−0.38	[−1.52; 0.86]	−0.16	[−0.68; 0.39]
Gait Speed Single-task (m/s)	0.99 (0.37)	0.88 (0.27)	−0.11	[−0.28; 0.05]	−0.34	[−0.89; 0.20]
Gait Speed Dual-task (m/s)	0.89 (0.39)	0.77 (0.31)	−0.12	[−0.28; 0.05]	−0.37	[−0.92; 0.17]
CRT (s)	18.4 (10.1)	19.0 (7.9)	0.66	[−5.46; 3.72]	0.08	[−0.56; 0.65]
Rel. Pmax CRT (W/kg)	5.4 (1.9)	5.2 (2.0)	−0.20	[−1.00; 0.54]	−0.13	[−0.66; 0.39]
Grip Strength (N)	181 (73)	150 (54)	−31.3	[−66.3; −1.7]	−0.49	[−0.97; 0.03]
cSBP (mmHg)	120 (17)	126 (20)	6.9	[−2.9; 15.4]	0.36	[−0.17; 0.88]
cDBP (mmHg)	81 (8)	82 (11)	0.6	[−4.1; 5.5]	0.06	[−0.42; 0.56]
AIx@75 (%)	29.0 (11.1)	32.3 (9.6)	3.35	[−1.94; 8.37]	0.32	[−0.21; 0.85]
PWV (m/s)	11.2 (1.3)	13.9 (1.2)	2.65	[2.04; 3.26]	2.14	[1.36; 2.81]
SF-36: Total Score	76.5 (16.6)	73.2 (18.5)	−3.38	[−11.80; 5.35]	−0.19	[−0.67; 0.35]
AQoL-8D: Total Score	61.6 (12.8)	60.1 (13.4)	−1.54	[−8.0; 4.9]	−0.12	[−0.39; 0.61]
FES	22.9 (8.0)	24.3 (8.5)	1.38	[−2.87; 5.28]	−0.16	[−0.37; 0.63]

3.3. Cardiovascular Health

The oldest-old showed higher PWV (Δ = 2.65 m/s [2.04; 3.26], *g* = −2.14 [1.36; 2.81;]) as well as central systolic blood pressure values (Δ = 6.9 mmHg [−2.9; 15.4], *g* = 0.36 [−0.17; 0.88]) than the oldest-old. The 95% CI show that small as well as large effects were also compatible with the data (Figure A2). Central diastolic blood pressure (*g* = 0.06) as well as augmentation index (*g* = 0.32) showed trivial to small differences with wide confidence intervals (Table 1).

3.4. Psychosocial Wellbeing

We found trivial differences between age groups in the total scores of the three questionnaires ($0.12 < g < 0.19$) with wide confidence intervals (Table 1). The self-worth dimension of the AQoL-8D was the only dimension which showed moderate effects in favor of the oldest-old (Δ = −1.12 [−2.05; −0.30], *g* = −0.63 [−1.12; −0.15]). All other dimensions showed only trivial differences in perception of physical and mental health between age groups (see Table A1 for all dimensions).

Data are presented as mean with standard deviation (SD). Between-group differences are depicted (mean differences and hedge’s g) with 95% confidence intervals [95% CI]. SPPB = short physical performance battery; CRT= repeated chair rising test; cSBP = central systolic blood pressure; cDBP = central diastolic blood pressure; AIx@75 = augmentation index corrected for 75 beats per minute; PWV= pulse wave velocity; SF-36 = General Health questionnaire; AQoL-8D = Assessment of Quality of Life questionnaire; FES = Falls Efficacy Scale.

3.5. Correlations

We observed a very large positive correlation between age and PWV (*r* = 0.86 [0.78; 0.92]) (Figure A3). All other correlations between physical functioning, cardiovascular health or psychosocial wellbeing and age showed only trivial to small effects with wide confidence intervals. Moderate to large correlations were found between grip strength and gait speed in the single- (*r* = 0.51 [0.30; 0.68]) as well as in dual-task situation (*r* = 0.55 [0.35; 0.71]) (Figure A4). We also observed a large correlation between gait speed and relative power in the lower extremities in the chair rising test (single-task: *r* = 0.65 [0.48; 0.78]; dual-task: *r* = 0.69 [0.52; 0.80]) (Figure A5). We found trivial correlations between cardiovascular health and physical functioning parameters as well as moderate correlations between psychosocial parameters and single-task (AQoL: *r* = −0.38 [−0.58; −0.15]; FES: *r* = −0.41 [−0.60; −0.18]) and dual-task gait speed (AQoL: *r* = −0.44 [−0.62; −0.20]; FES: *r* = −0.41 [−0.60; −0.17]). The correlation matrices are depicted in Table 2.

Table 2. Correlation matrix of all measured variables.

	AIx@75 [%]	PWV [m/s]	Grip [N]	Gait ST [m/s]	Gait DT [m/s]	CRT [s]	CRT [W/kg]	SPPB Balance	SPPB Gait	SPPB CRT	SPPB Total	SF-36	AQoL
PWV [m/s]	0.34 [0.13; 0.55]												
Grip [N]	−0.12 [−0.36; 0.13]	−0.22 [−0.45; 0.03]											
Gait ST [m/s]	−0.09 [−0.34; 0.16]	−0.21 [−0.43; 0.05]	0.51 [0.30; 0.68]										
Gait DT [m/s]	−0.14 [−0.38; 0.12]	−0.21 [−0.44; 0.05]	0.55 [0.35; 0.71]	0.95 [0.91; 0.97]									
CRT [s]	0.10 [−0.17; 0.35]	0.23 [−0.03; 0.46]	−0.24 [−0.47; 0.02]	−0.41 [−0.60; −0.16]	−0.43 [−0.62; −0.19]								
CRT [W/kg]	−0.19 [−0.43; 0.07]	−0.23 [−0.46; 0.03]	0.54 [0.33; 0.70]	0.65 [0.48; 0.78]	0.69 [0.52; 0.80]	−0.46 [−0.64; −0.23]							
SPPB Balance	0.06 [−0.20; 0.30]	−0.09 [−0.34; 0.16]	0.38 [0.14; 0.58]	0.41 [0.18; 0.60]	0.40 [0.16; 0.59]	−0.40 [−0.60; −0.16]	0.16 [−0.11; 0.40]						
SPPB Gait	−0.02 [−0.27; 0.23]	−0.01 [−0.26; 0.24]	0.35 [0.11; 0.55]	0.78 [0.66; 0.86]	0.69 [0.52; 0.80]	−0.24 [−0.47; 0.02]	0.57 [0.37; 0.72]	0.30 [0.06; 0.51]					
SPPB CRT	−0.16 [−0.40; 0.09]	−0.17 [−0.41; 0.08]	0.32 [0.07; 0.52]	0.49 [0.27; 0.66]	0.43 [0.20; 0.62]	−0.65 [−0.78; −0.47]	0.56 [0.36; 0.72]	0.25 [0.00; 0.47]	0.41 [0.17; 0.60]				
SPPB Total	−0.05 [−0.29; 0.21]	−0.13 [−0.37; 0.13]	0.47 [0.25; 0.65]	0.74 [0.60; 0.83]	0.67 [0.51; 0.79]	−0.60 [−0.74; −0.40]	0.55 [0.35; 0.71]	0.75 [0.62; 0.85]	0.74 [0.59; 0.83]	0.72 [0.58; 0.83]			
SF-36	0.01 [−0.24; 0.26]	−0.09 [−0.33; 0.16]	0.10 [−0.15; 0.34]	0.26 [0.01; 0.48]	0.30 [0.05; 0.51]	−0.29 [−0.51; −0.03]	0.28 [0.02; 0.50]	0.16 [−0.09; 0.40]	0.06 [−0.19; 0.31]	0.27 [0.02; 0.48]	0.22 [−0.03;0.45]		
AQoL	−0.21 [−0.44; 0.04]	−0.07 [−0.32; 0.18]	−0.25 [−0.47; 0.00]	−0.38 [−0.58; −0.15]	−0.44 [−0.62; −0.20]	0.29 [0.03; 0.51]	−0.47 [−0.65; −0.24]	−0.01 [−0.26; 0.24]	−0.23 [−0.45; 0.04]	−0.30 [−0.51; −0.06]	−0.23 [−0.45; 0.03]	−0.64 [−0.76; −0.46]	
FES	−0.15 [−0.32; 0.11]	0.04 [−0.21; 0.29]	−0.29 [−0.51; −0.05]	−0.41 [−0.60; −0.18]	−0.41 [−0.60; −0.17]	0.29 [0.04; 0.51]	−0.39 [−0.59; −0.15]	−0.11 [−0.35; 0.15]	−0.36 [−0.56; −0.12]	−0.33 [−0.53; −0.08]	−0.34 [−0.54; −0.10]	−0.57 [−0.72; −0.37]	0.56 [0.36; 0.71]

Data are shown as correlation coefficient (r) with 95% confidence intervals.

4. Discussion

The present study examined physical, psychosocial, and cardiovascular health indices of older adults and the oldest-old of our society. Our results revealed that the age groups show relevant group differences in some physical functioning parameters, with the most-pronounced age-related differences manifesting on the cardiovascular level. Psychosocial wellbeing was similar in both age groups.

Physical decline is not linear, but accelerates with age [28]. In our population, age did not correlate strongly with most physical performance variables as we observed higher performance of the older adults only in few parameters. SPPB scores were similar in both age groups and higher than established norm values for primary health care patients 70 years and older in all subtests, except the repeated chair rising test [29]. The older adults were stronger solely in handgrip strength, which is correlated to bone mineral density and is applied to assess frailty and disability [30,31]. Our data therefore suggests that the strength in the oldest-old is compromised, which potentially indicates impaired bone health and a resulting higher frailty. Mean values in the older adults were slightly over the cut-off point for mobility limitations in community-dwelling older people (174 N for females, 258 N for males) while the oldest-old fell below that cut-off [32]. In total, 71% of the participants were below their respective threshold, indicating higher mobility limitations and an elevated risk of adverse events in the measured population [18,32]. Interestingly, even though the older adult group showed better mean values, handgrip strength did not correlate with age, implying that age in our population of seniors is not the primary cause of the differences in strength, and that other factors such as use of grip in daily life and strength training should be considered.

Older adults showed superior performance in gait speed compared to the oldest-old (Figure A1). This difference may have clinical implications as this parameter is oftentimes applied to assess adverse outcomes in primary preventive care measures, and cut-off points according to habitual walking speed can be used to assess the risk [33]. According to the literature, gait speed below 1.0 m/s may lead to death and hospitalization within 1 year [33]. Walking speed showed only a small to moderate correlation with age in our examined population, adding further notion to the interplay of a variety of confounders, which may impact physical functioning beyond age alone. Daily activity levels as well physical health at admission are relevant factors which need to be considered in order to further understand the aging process and how living in nursing homes affects the human body. We are not able to make conclusive assumptions as to if and to what extent the degenerative process occurred since institutionalization, as physical performance at committal was not established. Nonetheless, our findings show that age alone is not the primary cause of physical decline in our population, implying that functional mobility and, in turn, independent living cannot be attributed solely to aging.

Therapists in Swiss nursing homes perform activities in a group setting, and oftentimes do not differentiate or create a selection mechanism due to a lack of resources [2]. Physical functionality and strength should, therefore, be assessed individually in order to tailor effective exercise programs. By applying a simple and fast testing battery, such as the SPPB and handgrip strength, the relevant parameters can be assessed efficiently and accurately. These values would allow a tailored and specific approach according to residents' physical needs regardless of age in the form of selected gait, balance, and strength training according to the performance level.

While differences in physical performance were minimal between age groups, central systolic blood pressure as well as PWV were elevated in the oldest-old. In line with the scientific literature [34], this indicates higher cardiovascular risk with increasing age in our population. Cardiovascular aging is an important health determinant with arterial stiffness being an independent predictor of cardiovascular outcomes such as myocardial infarction, cognitive decline, stroke, as well as hormonal and metabolic dysfunctions [34,35]. Higher fitness is associated with reduced arterial stiffness in sedentary as well as in active populations [36]. In adult populations, research shows beneficial effects of physical activity on vascular health in dependence of exercise intensity [37]. Nonetheless, the effects of exercise on arterial stiffness in elderly patients are conflicting due to a lack of research in this field. Certain studies show that mild to moderate aerobic exercise reduces arterial stiffness in 50-year old individuals [38], while other authors found no reduction in PWV in 60-year olds at risk of cardiovascular disease after a high-intensity exercise intervention [39]. This implies reduced vascular adaptability with increasing age. This might be due to functional and structural properties of the vasculature. Regular exercise, applied long-term, can improve both vascular properties and provoke changes in structure and function [39]. Accordingly, life-long activity and its continuation even in old age become all the more relevant. Nonetheless, long-term effects of regular exercise in older adults and oldest-old residentials need to be examined in order to assess the effect sizes and to define reference values, which are limited to an upper range of 70 years of age [40]. In relation to normative data (10.9 m/s for septuagenarians), our data shows a continued increase of PWV with progressive age (11.2 and 13.9 m/s), implying an elevated risk for cardiovascular mortality. Starting at about 50 years of age, PWV has been shown to increase exponentially with age as previously summarized in a consensus document on arterial stiffness [40]. In fact, all participants in the oldest-old group show increased cardiovascular risk, independently of physical functioning (Figure A2). This finding undermines how age has a direct effect on vascular function. How the cardiovascular system adapts to exercise in octogenarians and nonagenarians should be a topic of further research in order to find applicable, safe, and effective training modalities in nursing homes.

Psychosocial wellbeing was similar between age groups. We found moderate correlations between psychosocial variables and lower extremity function in residential seniors, indicating that better physical functioning leads to lower fear of falling as well as better quality of life. Fear of falling was slightly higher in the oldest-old, but not classified as high risk [23]. Both age groups showed high values in all SF-36 dimensions, which speaks in favor of the care they receive in their daily life. Our population shows higher values independently of age in psychosocial wellbeing and quality of life than norm values established in other populations of individuals 85 years and older [41]. Observations recording social interactions of nursing home residents reveal that only 10% of their time awake (approximately 100 min.) is spent by interacting with other people, which includes nursing staff and caretakers [42]. Interestingly, the oldest-old showed higher values in self-worth than the older adults. This could in part be attributed to higher individual affective and motivational personality systems such as dispositional optimism [43]. Whereas the older adults are possibly reminiscing their lost abilities, the oldest-old show contentment and acceptance and therefore do not perceive their physical health as a limiting factor "anymore", which might beneficially affect their self-worth and mental health. Exercise programs in community settings have shown how improvements of quality of life after regular exercise go in line with physical improvements, and therefore possess high potential to impact residents in residential care [44,45].

Considering the biological aging processes, its occurrence and degree notably differs between individuals, and is strongly dependent on lifestyle, with physical activity levels playing an important role. Exercise interventions in the oldest-old have shown promising results, as the body is still capable of adapting to exercise stimuli even in very old and sedentary populations [46]. Average muscle fiber size, independent of physical ability, is preserved in old age [5], thus allowing specific exercise programs to target the oldest and inactive members of society and benefitting their health. According to observations in nursing homes, residentials spend solely 1% of the total time awake in active motion (taking steps), which corresponds to less than 10 min per day [42]. The systemic stimulus is therefore very low in everyday life. Exercise interventions targeting nursing home patients have shown improvements in disability status as well as combating late-life depression [47], but compared to non-residential seniors, they remain considerably less active. This sedentary lifestyle may weaken self-efficacy, adding to the already passive behavior, which feeds the vicious cycle of inactivity in residential seniors [48].

Exercise programs, which promote social activities and interaction between residents and encourage performing habitual tasks, should be included in daily activities [44,45]. Strength and functional mobility parameters of residents should be used to create training groups, thus allowing the content to address their needs more specifically. According to the ability of the different groups, the sessions should target endurance in daily movement patterns such as standing, sitting, and walking in combination with balance tasks and strengthening exercises to different degrees of intensity and/or training volume. This could strengthen functional movements crucial for independent living in a group setting without under- or overexerting residents on an individual level. To make further statements about the aging process in older adults and oldest-old, and the role as well as importance of exercise, longitudinal studies are necessary [49–51]. Our study shows that, in our examined population of residential seniors, inter-individual differences in a variety of physical, vascular, and psychosocial indices become more predictive for successful aging. Considering the impact of the aging population on public health factors, our data provide comparative data on age groups which are rarely examined. Our data provide information on health aspects which should be considered when designing adequate intervention strategies for nursing home residents while considering their physical and psychosocial predispositions.

4.1. Methodological Considerations

There are some limitations of the study which we need to mention. To understand the aging process and its impact on strength, cardiovascular health, and quality of life, longitudinal analyses are necessary. The sample size of the study is small due to the strict exclusion criteria. We made the age cut-off point according to Naro, Venturelli, Monaco, Toniolo, Muti, Milanese, Zhao, Richardson, Schena, and Reggiani [5], while other literature sets different age cut-off points (i.e., oldest-old >100) [52]. To classify the eldest population group more precisely and especially for applying the information in the field, further studies are necessary. Our data do not allow general conclusions of the respective age groups as, on one hand, the age span within the groups is large, and on the other hand, we found large inter-individual differences. Nonetheless, we report important information and exploratory data that contribute to the knowledge in the field. As most of our subjects were female residents, one must be careful in generalizing the information to males. The socio-economic background, especially their past physical activity and lifestyle were not collected, which would have provided deeper understanding in their health status. Nevertheless, the study assessed relevant health parameters in a variety of domains in very old residential seniors, which were free of common illnesses accompanied by old age. We were able to provide data on the interplay of physical, cardiovascular, and psychosocial health variables in a vulnerable population. Reference values in such old populations are largely lacking; nevertheless, we were able to compare relevant parameters to established norms for adult populations. Further studies should measure nursing home residents at committal and on a regular basis thereafter to provide insight into how living in an environment which releases them from physical tasks affects functionality and health.

4.2. Conclusions and Practical Applications

We found selective but small differences between older adults and oldest-old seniors in physical performance and psychosocial well-being and a large decline in vascular health with age, with notable inter-individual differences. We cannot attribute the findings solely to aging. Inter-individual differences in a variety of physical, vascular, and psychosocial indices were evident, and these parameters should be assessed regularly in order to tailor group-based exercise programs for nursing homes. The implementation and continuation of regular, group-based exercise programs with content based on physical performance parameters should therefore be a main goal in senior residences and nursing homes. Gait, strength, and balance exercises should be incorporated to different degrees in order to maintain or re-gain some independence and autonomy in old age. Bouts of aerobic exercise, in combination with gait training, should be encouraged to improve cardiovascular functioning, particularly in the oldest-old. Social aspects of exercise should be considered and interactions encouraged to maintain and improve psychosocial wellbeing and quality of life. Furthermore, reference values for physical as well as psychosocial health in older adults and oldest-old living in care settings should be a topic of further investigation.

Considering the aging population as well as inactive lifestyles in old age, our study provides important information for exercise interventions in older adults and oldest-old in order to properly design and tailor exercises and activity strategies which consider physical and psychosocial predispositions of the population.

Author Contributions: A.M., L.D., L.Z., and H.H. designed the study; A.M., R.R., and E.L. collected the data; A.M. did the statistical analysis; A.M. and O.F. prepared the manuscript; All authors revised the manuscript draft and approved the final version. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the local Ethics Committee (Ethikkommission Nordwest- und Zentralschweiz; ethical approval number: 2018-01123; date of approval: 09.08.2018).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: All data generated or analyzed during this study are included in this published article and Appendix A.

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Conflicts of Interest: All Authors declare that they have no competing of interests.

Abbreviations

AIx@75 = augmentation index corrected for 75 beats per minute; AQoL-8D = Assessment of Quality of Life Questionnaire; cDBP = central diastolic blood pressure; CRT = repeated chair rising test; cSBP = central systolic blood pressure; FES = Falls Efficacy Scale; PWV = Pulse Wave Velocity; SD = Standard deviation; SF-36 = General Health Questionnaire; SPPB = Short Physical Performance Battery.

Appendix A

Table A1. Results for all dimensions of the applied psychosocial questionnaires. Data are presented as mean with standard deviation (SD). Between-group differences are depicted (mean differences and hedge's g) with 95% confidence intervals [95% CI].

	Older Adults	Oldest-Old	*t*-Test			
	Mean (SD)	Mean (SD)	Mean Difference [95% CI]		Hedge's g [95% CI]	
SF-36: General Health	67 (19)	64 (17)	−2.8	[−11.8; 6.4]	−0.15	[−0.68; 0.36]
SF-36: Physical Functioning	68 (28)	61 (27)	−6.3	[−19.5; 7.5]	−0.23	[−0.73; 0.28]
SF-36: Physical Limitations	77 (33)	75 (38)	−1.9	[−19.1; 16.5]	−0.05	[−0.51; 0.49]
SF-36: Emotional Limitations	83 (33)	79 (38)	−3.7	[−20.6; 14.8]	−0.10	[−0.56; 0.44]
SF-36: Vitality	76 (16)	68 (22)	−8.6	[−17.6; 0.8]	−0.43	[−0.91; 0.06]
SF-36: Mental Health	78 (12)	75 (17)	−2.5	[−9.6; 4.6]	−0.16	[−0.66; 0.33]
SF-36: Social Functioning	89 (18)	88 (15)	−0.7	[−8.4; 8.2]	−0.04	[−0.54; 0.49]
SF-36: Bodily Pain	75 (27)	74 (22)	−0.7	[−12.2; 13.1]	−0.02	[−0.53; 0.51]
AQoL: Independent Living	7.6 (3.3)	8.6 (3.3)	0.9	[−0.76; 2.50]	0.28	[−0.26; 0.74]
AQoL: Pain	5.6 (2.7)	5.7 (2.3)	0.10	[−1.21; 1.26]	0.04	[−0.49; 0.55]
AQoL: Mental Health	16.0 (3.6)	15.3 (3.9)	−0.62	[−2.43; 1.23]	−0.16	[−0.65; 0.34]
AQoL: Life satisfaction	8.4 (2.0)	8.0 (2.2)	−0.42	[−1.48; 0.55]	−0.20	[−0.70; 0.29]
AQoL: Self-worth	6.0 (1.9)	4.9 (1.7)	−1.12	[−2.05; −0.30]	−0.63	[−1.12; −0.15]
AQoL: Coping	6.2 (1.8)	5.8 (2.0)	−0.35	[−1.22; 0.67]	−0.18	[−0.67; 0.35]
AQoL: Relationships	11.8 (2.4)	11.7 (2.9)	−0.16	[−1.48; 1.13]	−0.06	[−0.60; 0.43]

SF-36 = General Health questionnaire; AQoL-8D = Assessment of Quality of Life questionnaire; FES= Falls Efficacy Scale.

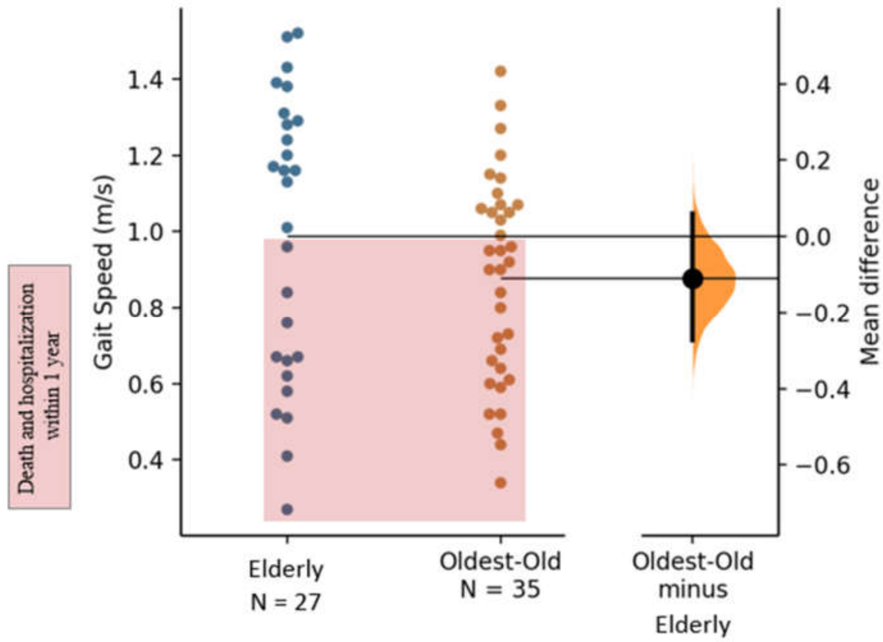

Figure A1. Individual datapoints of the older adults compared to oldest-old in single-task gait speed (m/s). Individuals in the red zone are at risk of death and hospitalization within one year according to Abellan van Kan et al. (2009).

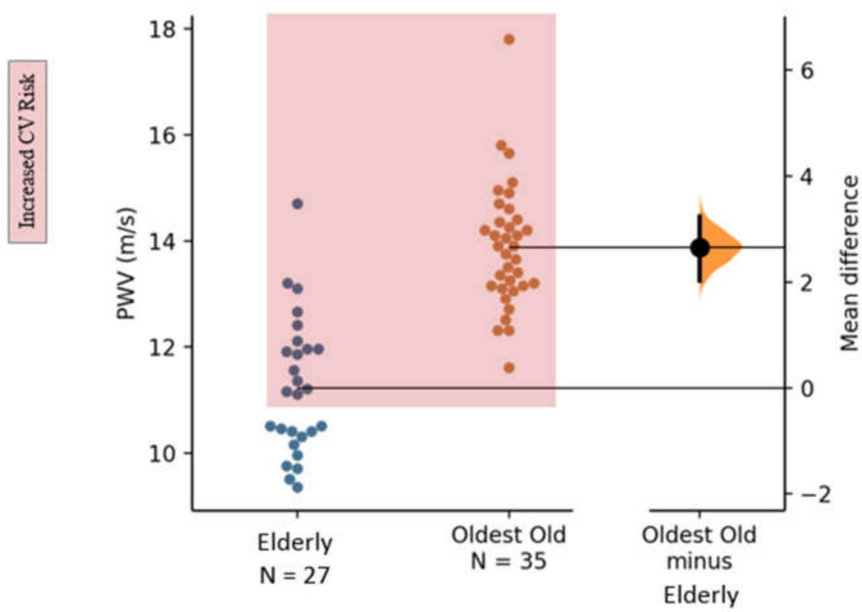

Figure A2. Individual datapoints of the older adults compared to oldest-old in PWV (m/s). Individuals in the red zone are at increased cardiovascular risk (Reference Values for Arterial Stiffness, 2010).

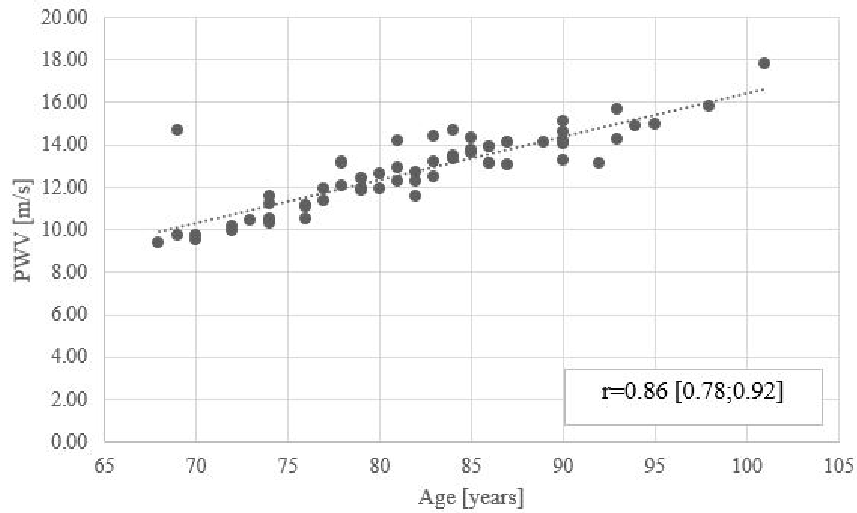

Figure A3. Correlation between age (years) and PWV (m/s).

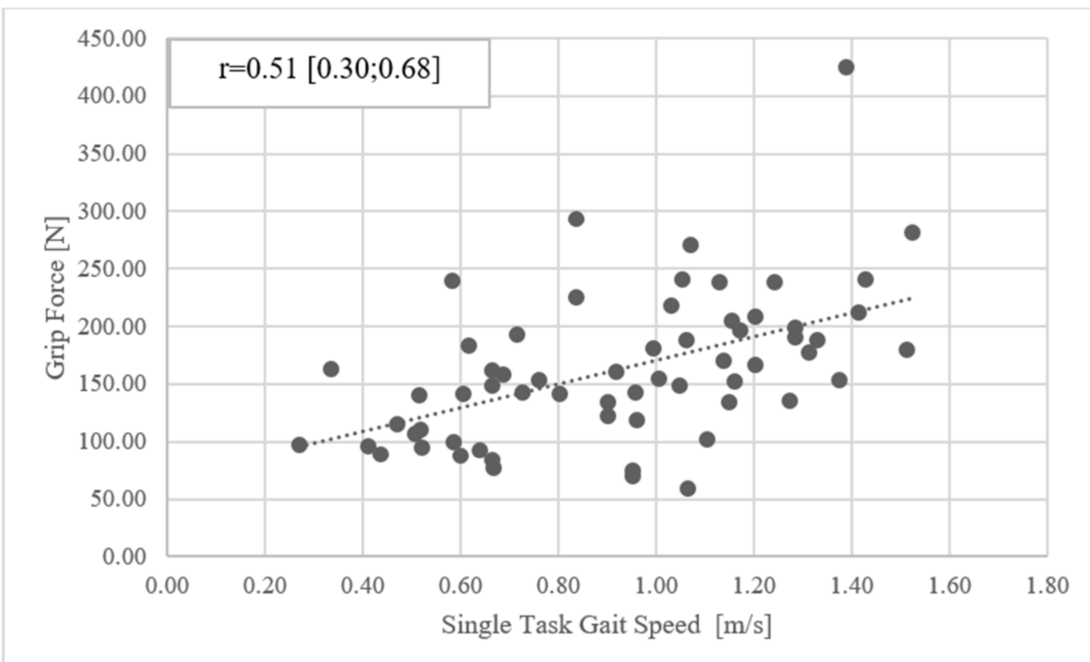

Figure A4. Correlation between handgrip strength (N) and single-task gait speed (m/s).

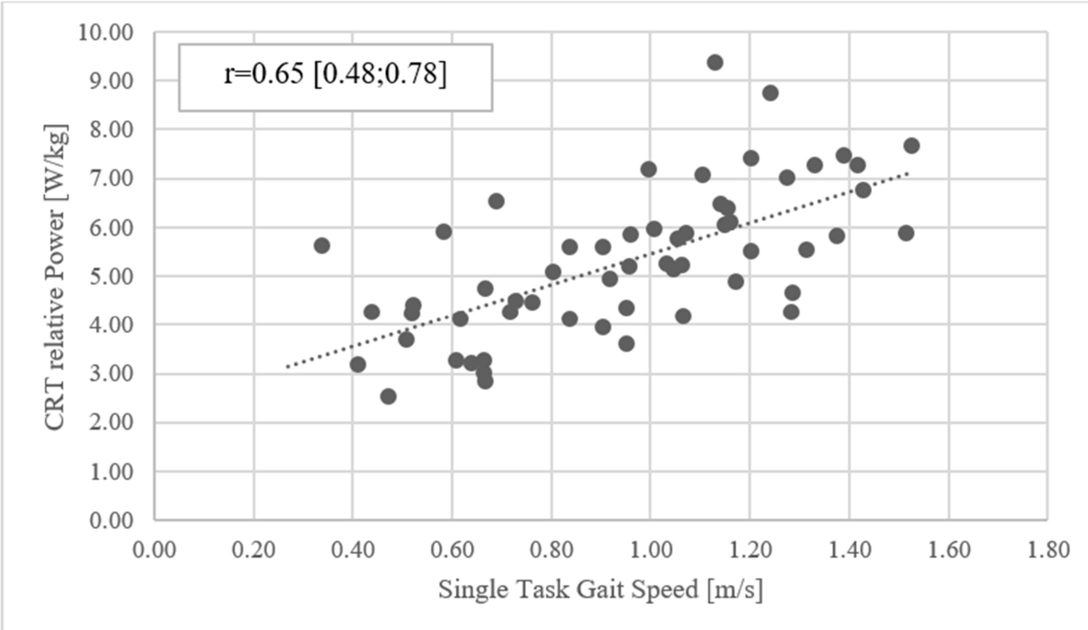

Figure A5. Correlation between relative power in CRT (W/kg) and single-task gait speed (m/s).

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Chapter 5

Publication 3

A cross-sectional analysis of motor competence and social-emotional skills by gender and age in preschoolers

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A cross-sectional analysis of motor competence and social-emotional skills by gender and age in preschoolers

Short title: Motor and social competence in preschoolers

Abstract

Background: Physical activity as well as social-emotional skills are fundamental for life-long physical and mental health. Studies show relevant gender differences in both motor skill proficiency as well as social-emotional conduct in children. Our study compared motor and social-emotional skills between ages and gender in preschoolers, in order to provide deeper insight into when these differences begin to manifest themselves.

Methods*:* Eighty-four preschoolers (female: 43; mean age: 4.9 (standard deviation 0.7) years; BMI-percentile: 0.58 (0.25)) from seven kindergartens participated in this cross-sectional study. We performed an adapted version of the Test of Gross Motor Development 2 and measurements of handgrip strength and jump force. Teachers filled out the Competences and Interests of Children questionnaire for each child. We calculated linear regressions, correcting for age and BMI-percentile in physical parameters and for age in social-emotional dimensions for gender and age differences.

Results*:* Girls showed better performance in skipping (β=0.58) while boys were better in kicking (β =0.62). No other gender differences were found. Moderate to large between-age differences were found in most gross motor subcategories and social-emotional dimensions with most pronounced differences between 4- to 6-year-olds and between 4- to 5-year-olds.

Conclusion*:* Our data does not confirm gender-based differences in locomotor or object control skills, nor in social-emotional competence. We attribute the level of motor skill proficiency to time spent performing and enjoyment of selected activities, not to biological factors in preschool age. Age, on the other hand, plays an important role in the development of strength as well as motor skills, whereby the maturation does not increase linearly as it does in social-emotional skills. Therefore, motor tasks in preschools should be individually adapted to proficiency while covering a wide spectrum of physical attributes.

Introduction

During childhood, learning and growth comes by and through movement, and promotes many different areas of development including physical, mental, social and emotional dimensions [1]. A stimulating environment is a prerequisite for cerebral adaptations in order to support healthy motor development in the first years of life, which result in increased strength and movement control [2, 3]. Studies indicate that children with underdeveloped motor ability are more likely to withdraw from physical play with other children and have fewer friends than their peers, resulting in avoidance or withdrawal from movement and exercise [4]. These physical limitations reduce the exposure to situations of social play, robbing them of the necessary environment to improve their motor as well as their social-emotional skills [5]. There is evidence that supporting and stimulating the development and practice of gross motor skills enables children to naturally apply them to the learning of other subjects and life-skills [6]. Additionally, children with delayed motor function oftentimes demonstrate higher levels of emotional, social and academic difficulties [7].

Therefore, gross motor skill development plays a major role in not only physical but also social-emotional maturation. On one hand, they provide the central nervous system with a wide spectrum of stimuli while on the other hand they represent the basis of more complex movement patterns [8]. Gross motor skills are often categorized in locomotor and object control skills which either enable locomotion or allow handling of external objects such as rackets or balls [9]. Research has shown differences in gender when it comes to physical activity levels as well as motor skill competence from a young age, with girls usually demonstrating higher scores in locomotor skills while boys score higher in object control [10-12]. Furthermore, the male gender and, in turn, high proficiency in object control, correlate with higher activity levels than locomotor skills and the female gender [13, 14]. These differences can be assumed to be caused by children's time spent engaged in the activities as well as to individual preferences, as physical maturation is similar until puberty in both genders [15]. Motor skills are, therefore, practiced and promoted in the areas that are of personal and social importance to the individuals. The socio-cultural setting is therefore of uttermost importance for motor and social learning as well as long-term health promotion.

Swiss kindergartens are coeducational and incorporate age-specific timeslots in their curriculum by teaching first- and second-year preschoolers separately on one afternoon per week [16]. Examining the interplay of gender and age on gross motor skill proficiency and social-emotional competence in preschool children might enable the identification of specific intervention strategies or activity recommendations to improve health-benefitting behavior at an early age. Therefore, the aim of this study is to compare gross motor competence, physical performance and social-emotional skills between genders and ages in preschool children. In line with literature, we expect boys to demonstrate higher object control and girls more pronounced locomotor skills. Additionally, we expect older children to have higher competences in both gross motor and social-emotional skills.

Methods

Study design and study population

Seven kindergartens in the canton Basel-Stadt, Switzerland, including 84 preschool children participated in this cross-sectional study. Children suffering from congenital heart defects or any other acute diseases or illnesses were excluded. We performed all measurements in the respective kindergartens. A team of trained and experienced assessors adhering to standard operation procedures conducted the tests. Kindergarten teachers were included in test standardization for the social-emotional questionnaires. The study protocol complies with the ethical standards of the Declaration of Helsinki and was approved by the local ethics committee (Ethikkommission Nordwest- und Zentralschweiz, ethical approval number: 2018-01123). The parents received all study information prior to enrollment and signed a written consent.

Gross motor skills and physical performance

Locomotor and object control skills were assessed using an adapted version of the "Test of Gross Motor Development, Second Edition" (TGMD-2) [17]. The TGMD-2 is a validated and reliable testing battery to establish motor competence in children between ages 3 and 10 (test-retest-reliability: $0.88 \leq r \leq 0.96$) [18]. The entire TGMD-2 battery includes 12 tests consisting of six locomotion (run, hop, gallop, leap, horizontal jump and slide) and six object control subtests (striking a stationary ball, stationary dribble, catch, kick, overhand throw and underhand roll). Striking, sliding and underhand throw were not included in the testing protocol as the movements are considered to be strongly linked to the American sport culture [19]. Therefore, a total of five locomotor and four object control skills were included in the testing battery. Each child performed one familiarization trial and two rated trials for each of the nine motor skills. Each skill had between three and four performance criteria which children were rated on by a dichotomic scale with "0" (fail) or "1" (pass). A maximal score of 56 points could be achieved in the locomotor and 22 points in the object control subtests. The Total TGMD-2 score is the sum of both subtests (maximum 78 points) and representative for the child's gross motor skill competence.

We measured handgrip strength (N) of the dominant hand with the Leonardo Mechanography GF® (Novotec Medical GmbH, Pforzheim, Germany) dynamometer, which have shown high reliability in children (test-retest-reliability: $0.81 \leq r \leq 0.91$) [20]. Children squeezed the handgrip device as hard as possible for a total of 5 seconds. The counter movement jump (CMJ) was performed on a force plate (Leonardo Mechanography® GRFP LT) and is a reliable and validated tool in young children (test-retest-reliability: r=0.98) [21]. Children were instructed to jump as high as possible and were allowed to use their arms during the jump. Maximal jump power in relation to their body weight (W/kg) was calculated using raw exported bodyweight and force data (sampling rate per sensor 500 Hz). For both tests, we used the mean values of two valid measurements for statistical analysis.

Social-emotional skills

To assess social-emotional skills of the children, preschool teachers filled out the "Competences and Interests of Children Questionnaire" (KOMPIK) for each child. The questionnaire is designed for children between the ages of 3.5 and 6, and is a widely used and validated pedagogical tool in German-speaking countries [22]. Three of the main developmental dimensions with their corresponding subcategories were assessed: social skills (cooperation, self-assertion), emotional skills (emotional regulation, empathy) as well as relationships and wellbeing (social relationships, psychological wellbeing). Each subcategory entails four to seven questions, which the teacher answered on a scale of 1-5, whereby a higher score represents higher competence in the respective domain. Maximum scores in the three domains are 70 points for social skills, 50 points for emotional skills and 55 for relationships and wellbeing. The maximum total KOMPIK score is 175 points.

Statistical analysis

We present the data as means with standard deviations (SD). For gender-differences, we calculated a linear regression, correcting for age and BMI-percentile in physical performance parameters and correcting for age in social-emotional dimensions. Data are presented as standardized effect sizes (β) with 95% confidence intervals. For age differences, one-way analysis of variance (ANOVA) were computed, whereby BMI-percentile was applied as covariate for all TGMD-2 subcategories and physical parameters [23]. A significance level of $p<0.05$ was set whereby we interpret the P values as a continuous measure of compatibility of the data with the statistical model and not relative to an arbitrary significance threshold [24]. Linear regression analysis were calculated for significant group differences, whereby the 4-year-olds were applied as reference group. Standard effect sizes can be interpreted as trivial ($\beta<0.2$), small ($0.2\leq\beta<0.5$), moderate ($0.5\leq\beta<0.8$) and large ($\beta\geq0.8$) [25].

Results

Study Population

The examined population consisted of 43 girls (age: 4.8 (0.7) years; height: 112.2 (5.8) cm; weight: 19.9 (3.0) kg; BMI-percentile: 0.57 (0.27)th) and 41 boys (5.0 (0.8) y.; 112.0 (6.3) cm; 19.9 (2.7) kg; 0.58 (0.24)th). 31 of the preschoolers were 4-year-olds (107.9 (4.7) cm; 18.5 (2.1) kg; 0.59 (0.29)th), 39 were 5-year-olds (113.3 (4.7) cm; 20.4 (3.0) kg; 0.58 (0.22)th) and 14 were 6-year-olds (118.3 (5.2) cm; 21.8 (2.4) kg; 0.54 (0.29)th).

Gender differences

We found mainly negligible to small differences between genders in nearly all subcategories of gross motor tasks and physical performance measures. Boys achieved moderately higher values in kicking than girls ($\beta=0.62$ [0.22;1.03]), with small to large effects being also compatible with the data. Girls were moderately better in skipping with trivial to large effects being compatible with the data ($\beta=0.58$ [0.18;0.99]). Social-emotional dimensions of the KOMPIK questionnaire showed trivial to small differences between genders ($-0.27\leq\beta\leq0.001$) with 95% CI being compatible with moderate differences (Table1).

Table 1: Difference between boys and girls in all parameters. Data is presented as mean with standard deviation (SD). Between-group differences are shown as linear regression estimates with 95% confidence intervals [95% CI] and standardized mean differences (SMD) with corresponding 95% CI. Physical performance data is corrected for age and BMI-percentile while social-emotional dimensions are corrected for age.

	Boys (n=41)	Girls (n=43)	Mean Difference [95% CI]		beta [95% CI]		p-value
	Mean (SD)	Mean (SD)					
Running (Locomotor)	6.8 (1.3)	5.9 (1.8)	0.73	[0.07;1.40]	0.45	[0.04;0.86]	.40
Galloping (Locomotor)	4.8 (2.0)	5.3 (1.7)	-0.53	[-1.35;0.30]	-0.28	[-0.73;0.16]	.21
Hopping (Locomotor)	9.4 (4.5)	10.4 (4.3)	-1.81	[-3.47;-0.15]	-0.41	[-0.79;-0.03]	**.03**
Leaping (Locomotor)	2.9 (2.2)	2.1 (2.1)	0.62	[-0.32;1.56]	0.28	[-0.14;0.71]	.19
Horizontal Jump (Locomotor)	5.6 (1.9)	5.4 (1.9)	0.10	[-0.72;0.92]	0.05	[-0.39;0.49]	.81
Skipping (Locomotor)	2.8 (2.2)	3.7 (1.8)	-1.19	[-2.02;-0.36]	-0.58	[-0.99;-0.18]	**.005**
Stationary Dribble (Object Control)	4.0 (3.6)	2.8 (3.2)	0.54	[-0.80;1.87]	0.16	[-0.23;0.55]	.43
Catching (Object Control)	3.9 (1.8)	4.0 (1.5)	-0.34	[-0.99;0.30]	-0.21	[-0.60;0.18]	.29
Kicking (Object Control)	5.2 (1.7)	3.9 (1.8)	1.17	[0.41;1.94]	0.62	[0.22;1.03]	**.003**
Throwing (Object Control)	5.2 (2.1)	4.5 (1.8)	0.55	[-0.29;1.4]	0.28	[-0.15;0.73]	.20
Locomotor Skills	32.3 (9.1)c	32.8 (9.1)	-2.26	[-5.74;1.22]	-0.25	[-0.63;0.13]	.20
Object Control Skills	18.3 (6.6)	15.2 (6.1)	1.92	[-0.54;4.39]	0.30	[-0.08;0.68]	.12
TGMD-2	50.7 (13.6)	48.0 (12.2)	-0.30	[-4.65;4.34]	-0.02	[-0.36;0.34]	.90
Handgrip Stength [N]	85.3 (18.7)	75.6 (19.4)	5.90	[-1.08;12.9]	0.30	[-0.06;0.66]	.10
Jump Power [W/kg]	0.53 (0.12)	0.51 (0.15)	-0.01	[-0.05;0.04]	-0.04	[-0.40;0.31]	.81
Social Skills	52.8 (10.4)	53.0 (13.5)	-2.46	[-7.16;2.24]	-0.21	[-0.59;0.19]	.30
Emotional Skills	38.9 (8.6)	39.9 (7.4)	-2.14	[-5.41;1.13]	-0.27	[-0.68;0.14]	.20
Relationships and Well-being	44.3 (6.7)	43.6 (8.1)	0.01	[-3.19;3.21]	0.001	[-0.43;0.44]	.99
KOMPIK Total Score	135.9 (22.4)	136.4 (26.0)	-4.59	[-14.27;5.09]	-0.19	[-0.59;0.21]	.35

SD= standard deviation; TGMD-2 = Test of Gross Motor Development 2; 95% CI = 95% confidence intervals; SMD = standardized mean differences. Subcategories of locomotor as well as object control skills are noted in parentheses.

Age-group differences

We found differences between all age groups in most measured subtests (Table 2). Corrected for BMI, most pronounced differences were found between 4- and 6-year-olds, whereby the largest difference were found in dribbling (β=1.46 [0.89;2.03]) and handgrip strength (β=1.52 [0.98;2.06]). Largest differences between 5- and 6-year-olds were also found in dribbling (β=0.91 [0.36;1.46]) while largest differences between 4- and 5-year-olds were found in catching (β=0.87 [0.45;1.29]) and jump power (β=0.89 [0.48;1.30]. Between-age differences in all physical parameters are depicted in Figure 1 with 4-year-olds as reference group. KOMPIK questionnaire showed largest differences in social dimension between 4- and 5-year-olds (β=0.90 [0.47;1.34]) as well as between 4- and 6-year-olds (β=1.18 [0.61;1.75]) but not between 4- to 5-year-olds (β=0.28 [-0.27;0.83]). Figure 2 shows age differences in social-emotional dimensions with 4-year-olds as reference group.

Table 2: Age group differences for all parameters. Data is presented as mean with standard deviation (SD). Physical parameters of ANOVA were corrected for BMI-percentile.

	Age Group	Mean (SD)	ANOVA p-value
Running (Locomotor)	4-year-olds	5.9 (1.5)	.04
	5-year-olds	6.4 (1.6)	
	6-year-olds	7.2 (1.5)	
Galloping (Locomotor)	4-year-olds	4.8 (2.2)	.53
	5-year-olds	5.2 (1.6)	
	6-year-olds	5.4 (1.8)	
Hopping (Locomotor)	4-year-olds	8.1 (4.6)	<.001
	5-year-olds	10.1 (3.9)	
	6-year-olds	13.7 (1.9)	
Leaping (Locomotor)	4-year-olds	1.8 (2.2)	.03
	5-year-olds	2.6 (2.1)	
	6-year-olds	3.6 (2.1)	
Horizontal Jump (Locomotor)	4-year-olds	5.1 (2.1)	.08
	5-year-olds	5.5 (1.7)	
	6-year-olds	6.4 (1.5)	
Skipping (Locomotor)	4-year-olds	2.7 (2.1)	.04
	5-year-olds	3.4 (1.8)	
	6-year-olds	4.4 (2.1)	
Stationary Dribble (Object Control)	4-year-olds	1.7 (2.5)	<.001
	5-year-olds	3.6 (3.4)	
	6-year-olds	6.6 (2.8)	
Catching (Object Control)	4-year-olds	3.0 (1.5)	<.001
	5-year-olds	4.4 (1.5)	
	6-year-olds	4.9 (1.5)	
Kicking (Object Control)	4-year-olds	3.9 (1.8)	.03
	5-year-olds	4.8 (1.9)	
	6-year-olds	5.3 (1.7)	
Throwing (Object Control)	4-year-olds	4.4 (1.9)	.28
	5-year-olds	5.1 (1.8)	
	6-year-olds	5.2 (2.3)	
Locomotor Skills	4-year-olds	28.1 (9.1)	<.001
	5-year-olds	33.1 (8.1)	
	6-year-olds	40.7 (4.7)	
Object Control Skills	4-year-olds	13.0 (4.9)	<.001
	5-year-olds	17.8 (6.3)	
	6-year-olds	22.0 (5.7)	
TGMD-2	4-year-olds	41.2 (11.9)	<.001
	5-year-olds	50.9 (10.3)	
	6-year-olds	62.7 (8.5)	

Handgrip Strength [N]	4-year-olds	68.4 (17.0)	<.001
	5-year-olds	83.7 (17.7)	
	6-year-olds	97.3 (12.8)	
Jump Power [W/kg]	4-year-olds	0.43 (0.10)	<.001
	5-year-olds	0.55 (0.13)	
	6-year-olds	0.61 (0.12)	
Social Skills	4-year-olds	45.5 (14.2)	<.001
	5-year-olds	56.3 (8.2)	
	6-year-olds	59.6 (6.8)	
Emotional Skills	4-year-olds	35.2 (9.3)	<.001
	5-year-olds	42.0 (6.3)	
	6-year-olds	41.4 (4.7)	
Relationships and Well-being	4-year-olds	41.6 (9.0)	.09
	5-year-olds	45.3 (6.3)	
	6-year-olds	45.2 (4.8)	
KOMPIK total Score	4-year-olds	122.3 (30.3)	<.001
	5-year-olds	143.6 (15.7)	
	6-year-olds	146.3 (12.4)	

SD= standard deviation; TGMD-2 = Test of Gross Motor Development 2. Subcategories of locomotor as well as object control skills are noted in parentheses.

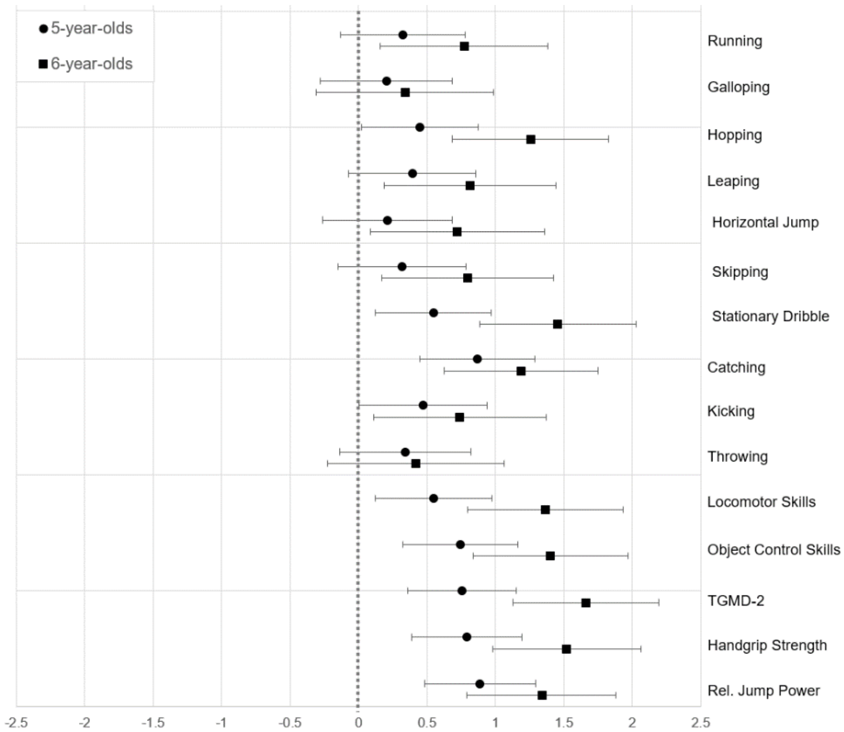

Figure 1: Between-age group differences in gross motor skills and physical performance corrected for BMI-percentile depicted as effect sizes with 4-year-olds as reference group.

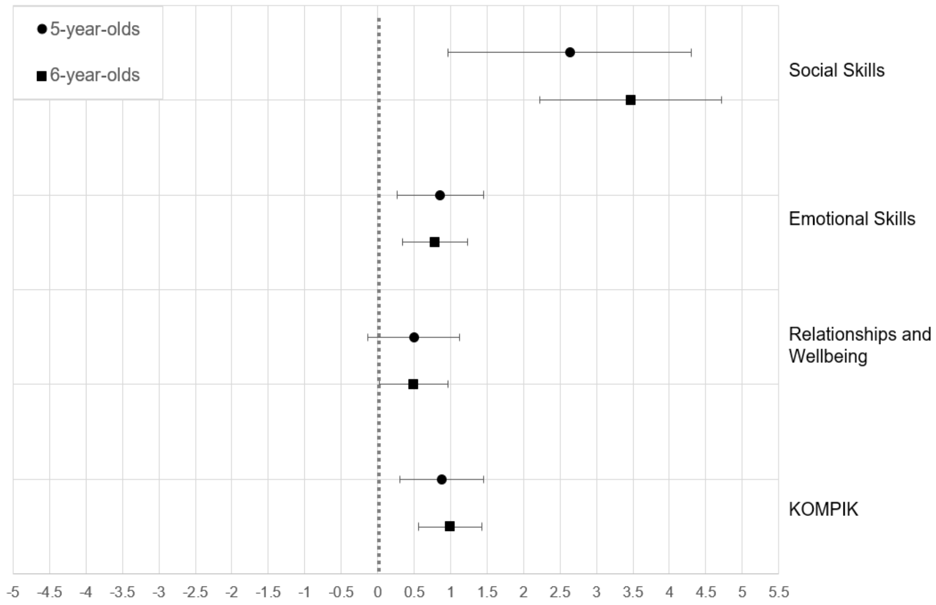

Figure 2: Between-age group differences in social-emotional skills depicted as effect sizes with 4-year-olds as reference group.

Discussion

Our study aimed at comparing gross motor competence, physical performance and social-emotional skills between genders and ages in preschoolers. We found small to negligible differences between genders in most motor skills as well as in social-emotional competence, contesting current literature. Trivial to moderate differences between genders were found solely in running, kicking and total object control skills. Our results show an increase in motor skills and social-emotional competence with age. Gross motor skills increased more during the later preschool age whereas social-emotional skills rose linearly.

Looking at their biological predispositions, healthy developing girls and boys are equal in weight, height and body composition during preschool age [15]. Contrary to literature [10-12], our examined children do not strongly differ in locomotor skills except in skipping and kicking, while all other skills showed only small differences. These differences in motor proficiency might be better explained by socio-cultural factors and time spent performing and engaging in selected activities as well as enjoyment in performing the tasks than by biological predispositions and development. Consequently, further studies should investigate the influence of individual preferences as well as the nature and degree of exposure to activities in relation to gender and motor proficiency. Our results encourage kindergarten teachers as well as parents to not exclude or limit exercise or activities based on gender. Additionally, we were not able to find gender-based differences in social-emotional competence which, according to literature, reveal themselves at a young age and persist through high school [27]. Abundant studies have shown boys to have higher rates of developmental problems, involving disruptive behavior such as strong tendencies to externalize emotions, while females display higher prosocial behaviors and better emotional regulation [27, 28]. These differences have a large impact not only on success as well as treatment in school and workplace, but also on public health outcomes [29]. Our data does not confirm these findings and therefore poses the question as to when these differences begin to manifest themselves and what environmental or cultural factors evoke them.

Age, on the other hand, plays an important role in the development of strength as well as gross motor skills during pre-school years. This seems most evident in motor skills possessing a high-power component such as leaping, skipping, jumping and hopping. While the 6-year-olds unsurprisingly show higher scores than 4-year-olds, they are also better than the 5-year-olds, wherein the differences between 4- and 5-year-olds remain small to moderate. Taking the superiority of the 6-year-olds into account, especially in locomotor control and handgrip strength, one might postulate that in pre-school age, neuromuscular development does not increase in a linear manner, but goes through bouts and phases. Strength has been shown to increase in a linear manner from age 6 onward until puberty in the lower extremities [30] as well as in handgrip strength [31]. Considering current literature on youth athlete development, the Swiss approach of age-specific time slots in preschools should be viewed with certain reservations. Van Hooren and De Ste Croix [32] argue that generic sensitive periods do not exist in a child's development and, therefore, should not be used or considered when training youth athletes. The focus should instead lie in training all physical attributes – strength, coordination, speed and agility – during all stages of development. Applied to our population, all age groups should be confronted with a broad spectrum of movement patterns, albeit with adaptations to individual capacity and proficiency in exercise complexity. This is especially important considering long-term healthy and active behavior, as higher motor skill proficiency goes in line with higher perception of that competence which, in turn, correlates with positive engagement in physical activity and organized sport [33]. Age, therefore, should be regarded as a reference in task complexity, but not in the underlying skills involved or characteristics of the exercise.

On a social-emotional level, the 4-year-old children differ strongly from their elder peers whereas 5- and 6-year-olds show similar values. This might be attributed to the 4-year-olds starting preschool and not having similar and as much exposure to unknown and different environments as the older children. Considering aspects of social interactions and social learning, keeping the age groups together is to be encouraged, as younger children can learn from older ones and the older ones can take on a role of leadership and responsibility towards the younger ones. Research on social learning speak in favor of heterogeneous group constellations in childhood, as they teach children to change perspective, take on new roles of responsibility and improve overall social and communication skills [34-36]. Intervention strategies in preschool children should therefore consider individual proficiency in gross motor skills and should include social activities to expose the children to challenging situations.

Methodological considerations

There are some limitations of the study to be considered. In order to understand the developmental processes and their impact on gross motor development and social-emotional dimensions during childhood, longitudinal analyses are necessary. Nevertheless, this study provides important data contesting the current notion of gender-based differences in physical abilities as well as social conduct. The Swiss preschool system is a coeducational system, which incorporates slots into their curriculum dedicated to age-specific activities without any differentiation based on gender. Current literature on this subject examined populations in different school systems and socio-cultural environments in which genders possibly still follow more traditional gender roles. The data is therefore to be interpreted with caution, and cannot be transferred into all cultures and educational systems. A further limitation of the study are the subjective instruments applied. Nevertheless, the staff as well as teachers followed strict measurement procedures in order to minimize the bias.

Conclusion

Our findings do not confirm the gender-based differences in motor as well as social-emotional skills in preschool children. Socio-cultural factors seem to play a crucial role in this context, whereby the exposure to activities, individual preferences, environment and age are more likely the relevant factors compared to gender. Equal opportunities in regard of physical activity and chosen movement patterns or games should be provided independently of gender. Furthermore, the exposure to activities should be introduced in a gender-neutral way and coeducational lessons should be promoted, even in physical education classes which are predominantly taught by separating genders [37]. In order to encourage health-benefitting behavior and a positive predisposition and attitude to exercise, preschool teachers can incorporate skill-specific sessions into their curriculum, whereby motor tasks should be adapted to proficiency and individual levels while covering a wide spectrum of physical attributes and promoting social learning between ages.

Key messages:

- Gender is not the deciding factor in gross motor skill proficiency or social-emotional competence in preschool age.
- Age plays an important role in the development of gross motor skills and strength, whereby gross motor proficiency does not increase linearly as in social-emotional skills.
- Individual proficiency in gross motor skills need to be considered and should include social activities to expose children to challenging situations.

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Contributions

AM, LD and HH designed the study; AM and SW collected the data; AM and EL did the statistical analysis; AM and OF prepared the manuscript; all authors revised the manuscript draft and approved the final version.

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Chapter 6
Publication 4

Effects of a cluster-randomized exercise intervention on cardiovascular health in preschoolers

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Effects of a cluster-randomized exercise intervention on cardiovascular health in preschoolers

Alice Minghetti[1], Oliver Faude[1], Lars Donath[2], and Henner Hanssen[1]

Abstract

Primary health prevention in at-risk children is receiving increased attention while less information is available on cardiovascular profile and response to exercise in healthy children. Our study examined the effects of a gross motor skill-based exercise intervention on micro- and macro-vascular health in preschoolers. This is a sub-study of a five-armed clinical trial with six kinder-gartens and 68 children. Four kindergartens were assigned to the intervention group (INT) and two to control groups (CON). We performed gross motor skill assessment (TGMD-2), static retinal vessel analysis, and measurements of central hemodynamics before and after the intervention. INT received one weekly exercise session for 25 weeks, while CON received no intervention. We calculated linear regressions correcting for age, sex, BMI-percentile, and baseline. We observed favorable effects in TGMD-2 for INT over CON (Cohen's d = 0.52 95% CI [0.15; 0.90]). Trivial between-group differences were observed in retinal vessel diameters ($0.08 < d \leq 0.29$) and trivial to moderate differences in all other arterial stiffness parameters ($-0.55 < d \leq 0.31$). Motor-skill based interventions are sensible measures to incorporate physical activity in pre-schools and improve gross motor proficiency at a very young age. The potential of motor skill-based interventions as primordial prevention strategy in healthy preschoolers needs to be further investigated.

Keywords

retinal vascular imaging, motor skills, children, prevention

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Introduction

Childhood plays an important role in determining healthy lifestyle behavior in adulthood, with physical activity playing a crucial role in this development (Blows, 2003). Many childhood physical activity programs foster the development of fundamental movement skills (FMS) during early childhood years, as they require high levels of coordination and build the base of more specialized movement sequences (Gallahue and Donnelly, 2003). Considering long-term health and active behavior, high motor skills proficiency is known to correlate with a higher perception of self-competence which, in turn, stimulates positive engagement in physical activity and participation in organized as well as unorganized sports (Barnett et al., 2008).

The World Health Organization considers physical inactivity a global health problem, as 23% of adults and 81% of adolescents are inactive and do not meet exercise guidelines (WHO, 2018). Physical inactivity is strongly related to annual deaths and non-communicable diseases such as heart disease, stroke, and diabetes, resulting in immense individual and economical burdens (WHO, 2018). Hypertension and arterial stiffness are considered independent predictors for cardiovascular events (Chen and Wang, 2008) and a recent meta-analysis was able to show an association between arterial stiffness and obesity, blood pressure, and physical activity already in primary school age (Lona et al., 2021b).

Alongside blood pressure, analysis of retinal vessel diameters has been applied more frequently as a valuable biomarker for cardiovascular risk assessment (Liew et al., 2008). In recent years, this tool has been readily applied in children. In fact, studies demonstrate the association of obesity, blood pressure, and physical activity behavior with retinal vessel diameters in primary school children (Kochli et al., 2018).

Primary prevention measures in childhood aim at treating risk factors to prevent cardiovascular disease and are becoming a center of attention for health-promotion facilities, with a strong focus on obese and at-risk children (Canadian Task Force on Preventive Health, 2015; Van Grieken et al., 2012). Less information is available on the response to exercise and the cardiovascular profile as means to implement primordial prevention strategies in healthy children, which refer to avoiding the development of risk factors in the first place (Gillman, 2015).

Aim

To measure the efficacy of an exercise intervention on gross motor skills as well as cardiovascular health outcomes in healthy preschool children.

Methods

Study design and study population

This is a sub-analysis of a five-armed clinical trial (Minghetti et al., 2021b) which examined the effects of an intergenerational exercise training program on physical health in preschoolers and residential seniors in Basel-Stadt, Switzerland. The main study was a five-armed study, in which a total of six kindergartens and 72 children were included. As two of the kindergartens were paired with nursing homes, we had to allocate the kindergartens according to their geographical location in order for the study to be conductible and were not able to properly cluster-randomize the study arms. We excluded children with congenital heart defects or any other acute or chronic diseases.

This sub-analysis examines pre-defined secondary health outcomes. As the two intervention groups of the main trial were designed to be comparable, we were able to combine them in this analysis and compare the four kindergartens from the intervention group (INT) to the two kindergartens in the control condition (CON). We complied with the ethical standards of the Declaration of Helsinki and the study was approved by the local ethics committee (Ethikkommission Nordwest-und Zentralschweiz, ethical approval number: 2***-***23). All parents received the study information prior to enrollment and signed a written consent.

Intervention

The intervention consisted of gross motor skills being practiced in a group setting. The exercises comprised various object control skills (throwing, aiming, rolling, and catching a variety of objects) as well as locomotor tasks (jumping, hopping, and rolling as well as dynamic balance exercises such as walking forwards, backwards, and sideways, over objects such as ropes or instable surfaces). We performed a total of 25 weekly exercise sessions lasting 45 min each with the intervention group which were distributed over an academic year, taking kindergarten holidays into account. Professional exercise coaches conducted all exercise training sessions and planned them in a progressive and variable manner. The control group received no exercise intervention and we asked them to uphold their normal kindergarten activities.

Testing procedures and anthropometric measures

We performed all measurements in the respective kindergartens according to standard procedures by trained staff. As exercise has a direct effect on hemodynamic measurements, we performed all cardiovascular health assessments prior to the fundamental movement skills (FMS) testing battery. This ensured a standardized protocol without interference between measured parameters.

We calculated height barefooted to the nearest 0.1 cm using a wall-mounted stadiometer (Seca 206, Seca, Basel, Switzerland). We determined body weight barefooted and in light clothing to the nearest 0.1 g using an electric scale (Seca 899, Seca). We used the Centers for Disease Control and Prevention child reference dataset (CDC, 2018) to calculate BMI-percentile.

Fundamental movement skills

We assessed FMS using an adapted version of the "Test of Gross Motor Development, Second Edition" (TGMD-2) (Ulrich, 2000). The TGMD-2 is a validated and reliable testing battery to establish motor competence in children between ages 3 and 10 (Cools et al., 2009; Valentini, 2012). The entire TGMD-2 battery includes 12 tests consisting of six locomotion (run, hop, gallop, leap, horizontal jump, and slide) and six object control subtests (striking a stationary ball, stationary dribble, catch, kick, overhand throw, and underhand roll). As striking, sliding and underhand throw are considered to be strongly linked to the American sport culture (Morgan et al., 2013), we excluded them in the test protocol. Therefore, we included a total of five locomotor and four object control skills in the test battery. Each child performed one familiarization trial and two rated trials for each of the nine motor skills. Each skill had between three and four performance criteria which children were rated on by a dichotomic scale with "0" (fail) or "1" (pass). A maximal score of 56 points could be achieved in the locomotor and 22 points in the object control subtests. The Total

TGMD-2 score is the sum of both subtests (maximum 78 points) and representative of the child's gross motor competence.

Retinal vessel analysis

We assessed retinal vessel diameters to address the secondary aim of the study, that is, to assess potential changes in the microvascular system. We analyzed central retinal arteriolar (CRAE) and venular (CRVE) equivalents using the Retinal Vessel Analyzer (SVA-T, Imedos Systems UG, Jena, Germany) and used them to define the arteriolar-to-venular diameter ratio (AVR) according to previously described standard analysis procedures (Hanssen et al., 2011; Hubbard et al., 1999). Retinal vessel analysis is highly reproducible in all age groups with an interclass correlation of 0.90–0.95 and coefficient of variation of 2% in young children (Endes et al., 2019). Data on the validity of using the retinal vessel imaging in children have recently been collected in our systematic review and meta-analysis in children (Kochli et al., 2018). An experienced examiner captured two images of each eye and we used the average of both images to calculate the three retinal parameters. Vessel diameters are presented in micrometers (μm). In the model of Gullstrand's normal eye, one measuring unit relates to 1 μm.

Blood pressure and arterial stiffness

We obtained markers of central hemodynamics as well as pulse wave velocity (PWV) using an oscillometric Mobil-O-Graph® PWA Monitor device (I.E.M. GmbH, Stoberg, Germany) with integrated ARCSolver® software (Hametner et al., 2013). This method has been validated and is in good agreement with the conventional tonometric method (Hametner et al., 2013; Wassertheurer et al., 2010). We placed the blood pressure cuff on the left upper arm while the child was resting in a supine position in a quiet room. We calculated mean values of three valid measurements for data analysis.

Statistical analyses

To establish the effects of the intervention compared to control condition, we calculated linear regression models for each parameter with the control group as reference. In all analyses, we applied pre-test values as well as sex and age as covariates in order to adjust for baseline values. For cardiovascular parameters, we also used BMI-percentile as covariate. Using the estimates and SD of baseline parameters, we calculated effect sizes (Cohen's d) with 95% confidence intervals which can be interpreted as trivial ($d < 0.2$), small ($0.2 \leq d < 0.5$), moderate ($0.5 \leq d < 0.8$), and large ($d \geq 0.8$) (Cohen, 1992). We present the supplementary data as median with interquartile range (IQR). For pre-post assessment, we performed Shapiro–Wilk normality tests for each variable and calculated a paired t-test with mean differences (Δ) as well as effect sizes (Cohen's d) with jamoviStats software.

Results

Study population

We assessed all 72 children in the selected kindergartens for eligibility and could include all of them (see supplementary Figure 1). During the study period, four children (6%) dropped out due to home relocation. This resulted in 68 children who completed the trial. In the main study, children were distributed in three study arms (intergenerational group, peer group, and control group), whereby two received the same exercise intervention in a different social setting and one was asked to uphold usual habits as a control condition. In this sub-analysis, we combined the two interventions arms, that is, the intergenerational and peer-groups (Minghetti et al., 2021b). This resulted in 46 children in the intervention group (female: $n = 23$; male: $n = 23$; mean age: 5.2 (standard deviation [SD] 0.6) years; mean BMI-percentile: 0.55 (SD 0.23)th). 22 children were assigned to the control group (female: $n = 12$; male: $n = 10$; mean age: 5.4 (SD 0.5) years; mean BMI-percentile: 0.60 (SD 0.25)th). There were no statistically significant differences in sociodemographic background, baseline values, or sex distribution between groups ($0.12 \leq p$-value ≤ 0.32) and did not influence statistical analysis. Flow chart of the sub-analysis can be found in the supplementary figure.

Fundamental movement skills

We found differences between the two groups in both dimensions of TGMD-2 (supplementary Table 1). Linear regression models show favorable effects for INT over CON in locomotor skills (d = 0.57 95% CI [0.20; 0.93]). Confidence intervals of the effect sizes in object control skills implicate a compatibility of the data with trivial to at least medium differences in favor of INT (d = 0.26 95% CI [-0.13; 0.65]).

Retinal vessel diameters

We found pre-post differences in both groups for retinal vessel diameters (supplementary Table 1). Changes in CRAE were trivial in both groups, whereby INT showed a tendency to increase while CON slightly decreased. CRVE showed small to moderate increases in both groups. Due to larger increases in CRVE than CRAE, AVR tended to decrease in both groups. Linear regression models implicate trivial to small differences in static retinal vessel parameters between groups (Figure 1).

Blood pressure and arterial stiffness

INT showed small to moderate increases in peripheral as well as central systolic and diastolic blood pressure while CON shows trivial to small decreases in central blood pressures. PWV showed trivial to small increases in both groups (supplementary Table 1). Linear regression models show moderate effects in favor of CON for central diastolic blood pressure ($d = -0.53$ 95% CI [-0.94;-0.12]). All other parameters show trivial to small differences between the groups (Figure 1).

Discussion

We examined the effects of a gross motor skill intervention program on development of fundamental movement skills and micro- and macro-vascular health in healthy kindergarten children. We

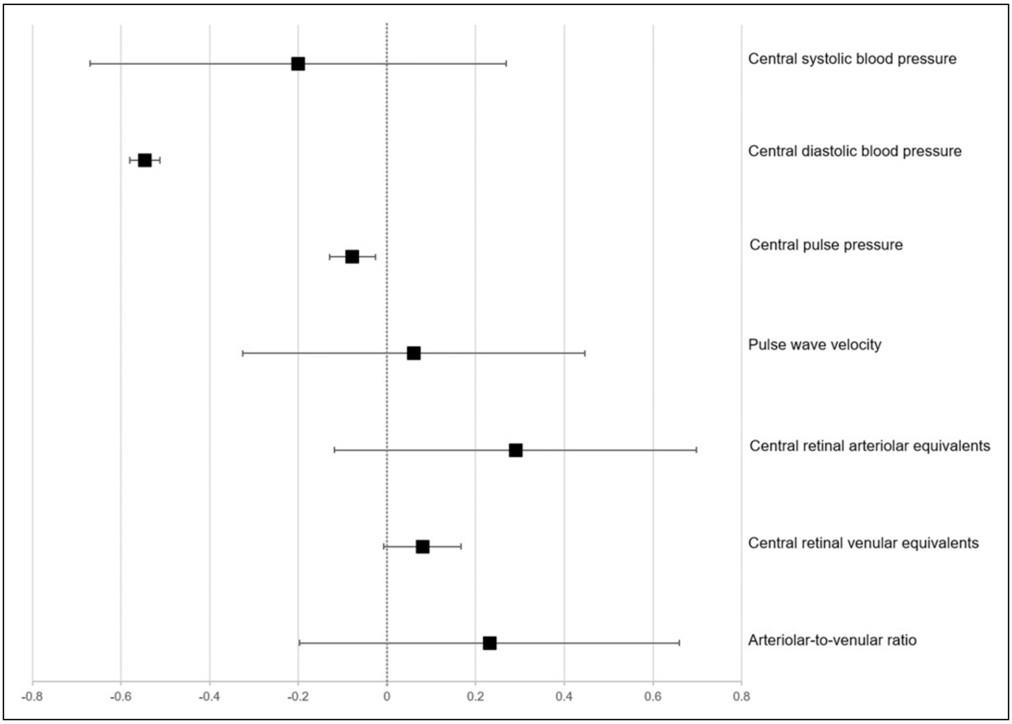

Figure 1. Effects of the intervention on cardiovascular health parameters compared to control condition, corrected for baseline values and age. Data presented as mean between-group differences with 95% confidence intervals.

performed 25 weekly exercise sessions and assessed gross motor skills, retinal vessel diameters, and central hemodynamic parameters prior and after the intervention.

Our analysis shows that while a gross motor skill-based intervention has favorable effects on FMS in healthy preschoolers, it did not affect micro- or macro-vascular health parameters. Our results carry important implications for exercise and health-promotion programs focusing on primordial prevention in childhood.

We are able to show that incorporating a low-threshold exercise program in pre-schools increases motor skill competence. This finding is important considering the cardiovascular health benefits of lifelong participation in sport activities and general fitness at later stages in life (Barnett et al., 2008; LeGear et al., 2012; Lubans et al., 2010). Cardiovascular diseases as well as other metabolic risk factors progress over time and can be detected at an early age (Veijalainen et al., 2016). Finding effective primary preventive measures to counteract early vascular dysfunctions is becoming all the more relevant. Exercise-based primary prevention strategies aiming at affecting lifestyle behavior and physical activity have been proven to be potent non-invasive tools to improve childhood cardiovascular risk (Lona et al., 2020; Andersen et al., 2006; Kochli et al., 2018).

For healthy children, such as our population, motor skill-based interventions are valuable for positively impacting physical performance, increasing the probability of adherence to long-term activity and participation in sport activities. Continuation of active lifestyle behavior is a prerequisite for optimal cardiovascular health over a lifespan. Gross motor skill-based exercise interventions during early childhood are an effective measure to improve motor skill performance and pave the path for higher motivation and better adherence to an active lifestyle in later years. These prospects are thought to be sufficient to promote FMS programs in the preschool curriculum as a primordial prevention approach in healthy young children.

We found that the exercise intervention did not have relevant direct impact on the hemodynamic measurements in the intervention group. We can attribute the lack of apparent effects of our exercise intervention on vascular parameters to a number of factors.

For one, our exercise program consisted of various motor skill tasks performed in constant motion, but at low intensities. Studies in adults have shown a dose–response relationship between exercise intensities and endothelial function, with higher aerobic exercise reducing arterial stiffness (Ashor et al., 2014, 2015). The intensity and duration of our study may not have been sufficient to evoke changes in vascular properties. Second, as our population consisted of healthy children between the ages of four and six, vascular adaptations were not inducible as their cardiovascular profile was not associated with elevated risk.

We were able to observe small adaptations in retinal vessel diameters. Despite small effects, our intervention group showed small increases in central retinal arteriolar equivalent, while the control group showed a small narrowing. The arteriolar-to-venular ratio decreased due to venular widening in both groups. It remains unclear why retinal venules widened in both groups. In six-year-old children with high blood pressure, a 10 min reduction of sedentary time per day has recently been associated with retinal arteriolar widening over a follow-up period of 4 years (Lona et al., 2021a). In adolescents, daily aerobic and coordinative exercises of 20 min duration over 8 weeks was able to increase retinal arteriolar diameters in conjunction with improvement in cognitive function (Ludyga et al., 2019). A systematic review found that children with higher cardiorespiratory fitness had favorably lower arterial stiffening (Lona et al., 2021b). Our FMS intervention did not induce adaptations in pulse wave velocity in our study. We can deduce the lack of vascular adaptations to the short intervention period as well as the focus on motor skills rather than aerobic exercise. In children below the age of six, vascular adaptation to exercise may be difficult to detect because of the dynamic cascade of neuroanatomical changes which occur in this young age group (Blows, 2003).

It needs to be stressed that these short-term motor skill-based interventions do not seem to impact vascular adaptations in this age group, neither on a microvascular nor on a macro-vascular level. Indication for exercise treatment to improve vascular function are rather given in older children with increased cardiovascular risk. As previous studies with primary school children have demonstrated, risk factors such as overweight or high blood pressure are correlated to retinal microvascular alterations early in life (Kochli et al., 2019; Lona et al., 2020).

Physical fitness has been linked with retinal vessel health and lower PWV in children (Kochli et al., 2019) and endurance training with obese prepubescent children is able to positively affect vascular health by reducing arterial stiffness (Farpour-Lambert et al., 2009).

Our study has proven itself feasible by increasing FMS, and further studies should examine the effects of such gross motor interventions in young children with pre-existing cardiovascular risk in order to assess whether such programs can be applied as effective primary preventive strategies. Additionally, our study was able to show that static retinal vessel analysis as well as assessment of pulse wave velocity are non-invasive, feasible tools in preschoolers and can be applied in future studies.

Limitations

Our study has several limitations which need to be addressed. As it is a sub-analysis of a larger study (Minghetti et al., 2021a), we did not calculate a sample size calculation for these secondary outcomes and the number of children per group is not balanced. We were not able to properly cluster-randomize the study arms due to numerous factors of the main study, which was mostly due to the senior populations. The children's baseline data does not show relevant differences between groups despite these limitations. The data should be interpreted with caution as the kindergartens participated voluntarily. This could have led to a potential bias by including kindergartens which are more active. As the parents signed the written consent form prior to study arm allocation, we can assume that the bias is minimized. The number of training sessions per week can be considered low. This was due to full curricula in kindergartens, which did not allow more than one additional exercise session per week. Despite the low number of sessions, the intervention was sufficient to elicit positive effects in FMS. As our study was able to reflect real-life application and integration of such an exercise program, the results of our study can be considered a faithful and generalizable representation of the impact of such programs.

Implications for practice

Pre-schools should encourage and promote fundamental movement skills in specific exercise sessions as they have been proven to support gross motor development. Kindergartens should provide opportunities to practice and develop physical attributes and a broad spectrum of movement patterns while adapting the task complexity to individual proficiency. This is especially important considering long-term health and participation in exercise, as higher perception of competence correlates with positive engagement in physical activity. The effects of such exercise sessions as means of primordial prevention needs to be further investigated.

Conclusion

We were able to show that motor skill-based interventions are sensible measures to incorporate physical activity in pre-schools and are beneficial for improvements in gross motor skill proficiency at very young age. Applying retinal vessel analysis and assessment of arterial stiffness under the age of six is feasible and safe.

In this young and healthy population, the short-term motor skill-based intervention did not induce a micro- or macro-vascular response and the influence as a potential primordial prevention strategy for cardiovascular health remains to be further investigated.

We recommend implementation of FMS interventions in young children to improve gross motor skill proficiency at a very early stage and to prospectively increase motivation and adherence to regular physical activity and active lifestyle, which are associated with long-term cardiovascular health benefits. In order to induce effects on the vascular system, intervention programs may need to focus more on aerobic-based exercise interventions in children older than 6 years of age in the presence of risk factors such as increased body mass index and blood pressure.

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Author Contributions

AM: designed the study, performed the measurements, conducted the intervention, analyzed the data, prepared the manuscript and approved the final version. OF: supported the statistical analysis and interpretation of the data, reviewed drafts of the paper and approved the final version. LD: designed the study and reviewed the final version. HH: designed the study, prepared the manuscript, reviewed drafts of the paper and approved the final version.

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Ethical Approval

Ethics approval number: 2,018–01,123

Data availability

The data that supports the findings of this study are available in the supplementary material of this article.

Trail Registration

Clinical trial registry: https://clinicaltrials.gov/ct2/show/NCT03739385

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Supplemental Material

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Chapter 7

Synthesis, discussion and outlook

Chapter 7 – Synthesis, discussion and outlook

My PhD project comprises the preparation, execution and analysis of a five-armed controlled trial called *"Generations on the Move: intergenerational exercise and health promotion"*, whereby the physical and psychosocial effects of intergenerational exercise training were compared to peer-group training and control conditions in preschool children and residential seniors. Besides summarizing, discussing and interpreting the main results of the study as well as the age-specific analyses, I will provide details and observations from the intervention. Furthermore, I will discuss the implications of the examined exercise approach as well as its practical applications and necessary considerations. Finally, I will present my outlook for this field of research.

7.1 Synthesis

The results of the *Generations on the Move Study* show that an intergenerational exercise intervention can, first and foremost, be realized and is feasible. Secondly, the results prove how the intergenerational exercise setting evokes a range of positive health benefits in both age groups. Furthermore, the exercise setting is deemed comparable and in certain dimensions more effective than peer-group training. Children showed largest benefits in motor skill proficiency while social-emotional skills developed similarly between study arms. Seniors improved all examined parameters of physical performance and health while also improving psychosocial profile and quality of life. The intergenerational setting can therefore be considered a promising strategy to promote exercise and shared activities in both generations.

Additionally, the *Generations on the Move Study* enabled a deeper insight into the physical and psychosocial predispositions and conditions of young children and the elderly. A cross-sectional analysis of the children's data allowed a comparison of motor competence and social-emotional skills by gender and age. We found that gender is not a deciding factor in any of the measured outcomes while age plays an important role in early childhood, especially in the developmental process of motor skills and strength. These findings support the notion that individual proficiency in gross motor skills should be considered when implementing exercise approaches in preschools and should include socially challenging situations. Additionally, we found that a motor skill-based intervention in young and healthy children favored motor capability but did not affect macro- and microvascular health parameters. Nonetheless, such improvements in fundamental movement skills can be considered valuable for long-term health. By providing children a strong foundation through a wide range of movement patterns, one can pave the path for life-long participation in sports, thus supporting long-term health. The effectiveness of motor skill-based interventions as a primordial prevention strategy for cardiovascular health nevertheless needs to be further examined. Both analyses of the children's data speak in favor of implementing exercise sessions, with a strong focus on motor skills, in preschools as they bring fort a variety of positive short-term effects which, according to literature, can impact children individually in the long-term [32, 108, 112]. The cross-sectional analysis comparing elderly with oldest-old residentials found small differences in physical performance and psychosocial wellbeing between age groups while vascular health declined with age. The results emphasize the importance of lifelong exercise, performed regularly, as age was not the determining factor impacting health variables. The findings recommend group-based exercise programs in residential care with gait, strength and balance exercises tailored to individual capacity and capability in order to maintain or re-gain independence and autonomy in age.

In conclusion, all publications from the presented study speak in favor of incorporating exercise training in the young and old, as both age groups can profit extensively not only on a physical, but also on a psychological, emotional and social level.

7.2 Main findings

The *Generations of the Move Study* provides a first insight into an unexamined field. On one hand, I was able to measure the physical and psychosocial health effects of an intergenerational exercise intervention, thereby providing evidence on how both generations profit from the setting. On the other hand, I could compare intergenerational to peer-group exercise as well as control conditions, showing comparable results between the exercise settings, with slight superiority for intergenerational groups in certain measured parameters.

7.2.1 Intergenerational benefits for children

The study provides a number of valuable and new information in the field of childhood exercise and health promotion. For one, I was able to show improvements in both physical performance and social-emotional skills in all three study arms, confirming the natural maturation process during childhood years. Secondly, the study supports the notion of incorporating motor-skill based sessions in kindergartens in order to improve fundamental movement skills (FMS) independently of group constellation, therefore positively influencing the developmental process [107]. Lastly, I could show that children in the intergenerational setting profit, especially in physical performance, compared to peer-group exercise and control conditions. Considering the age of the children (between four and six years old), this development carries relevant considerations for future exercise approaches in kindergartens. As described in the introduction, FMS represent basic movement patterns necessary to perform any other more complicated or specialized motor sequences [7]. Their improvement, therefore, is of high relevance considering life-long participation in organized and non-organized activities as well as in respect of long-term fitness and health [8, 9]. Higher competence and, more importantly, self-perceived competence in tasks go in line with higher self-esteem and therefore higher participation and inclusion in activities [32]. Considering the aspects of primordial prevention, this finding is of high relevance in regard of micro- and macrovascular health as well as cardiorespiratory fitness [141]. Although the motor skill-based intervention did not influence cardiovascular health parameters, the implementation of such programs is strongly recommended. By improving their FMS, the participating children were able to create a stronger foundation for any future sports participation, crucial for the continuation and maintenance of physical activity into adolescence and adulthood while supporting their biological development process. Such a solid foundation in gross motor competence is a prerequisite for the adherence to regular physical activity and an active lifestyle which, in turn, are associated with long-term cardiovascular benefits [140].

I was not able to provide unequivocal data for the social-emotional dimension, confirming the notion that such skillsets are formed over a longer time span [18]. Nonetheless, childhood plays an essential role as opinions, attitudes, relationship skills and the shaping of stereotypes, prejudices and personal views occur in childhood. These can shape and steer future development as well as personal views of the world and can be changed or influenced only to a limited extent later on in life [153]. Pedagogical studies report that children benefit most when they are exposed and actively involved in as many challenging and different settings as possible from an early age [19]. The intergenerational setting challenges children with a complex environment, encouraging them to change perspective, experience empathy and learn tolerance. Providing children with valuable, positive, empowering and engaging interactions with an older generation might not show immediate and acute effects, but could potentially manifest itself later in life. In order to determine if exposure at such young age indeed has such effects, long-term and follow-up studies are warranted.

7.2.2 Intergenerational benefits for seniors

Considering the senior participants, the data carries important revelations and practical implications. On the one hand, I could show how inactivity entails a rapid and relevant decline in physical performance in old age, shown by decreases in all measured parameters in our control condition. On the other hand, I was able to show that both intervention groups managed to slow down and counteract the biological aging process by not only maintaining, but by increasing physical performance in functional movement patterns which are highly relevant for independence in old age. Age alone, therefore, is not the primary cause of physical decline, increased frailty and loss of independence, but the accompanied inactivity. Especially noteworthy are changes in gait speed, as it is an important and vastly applied clinical tool to assess adverse outcomes, risk of falling and general frailty [85]. The habitual walking speed of the control group declined to a large and clinically relevant extent, exceeding the yearly decline of >0.15 m/s which is predictive for an increased risk of falling [154]. The intergenerational group, in contrast, was able to increase gait speed significantly, therefore reducing the risk of falling as well as general frailty and increasing independence [85]. Actively engaging residential seniors in repetitive motions of daily movement patterns such as standing, sitting down, walking in different directions and controlling light objects seems to be an effective strategy to increase crucial everyday functionality. Not only did the intergenerational group improve physical performance, but the intervention was also able to improve vascular profile compared to control conditions. Although the intervention did not entail endurance or cardiovascular characteristics, central systolic and diastolic blood pressure as well as pulse wave velocity declined. As age is the dominant risk factor for arterial stiffness and cardiovascular events, this is an important finding [96]. Daily activity in nursing homes has been reported to be strikingly low if not almost nonexistent [43]. The intervention, despite being of very low-threshold and dominated by motor tasks, provided a high enough stimulus to provoke beneficial vascular adaptations. We are not able to state whether our cardiovascular changes entail a reduction of risk, as reference values for our age groups do not exist [54]. The positive changes nevertheless imply a positive influence of replacing sedentary time with light to moderate activity even in very old and otherwise inactive individuals.

While both intervention settings benefit, to different degrees, the physical health of seniors, the presence of children has a larger impact on quality of life, perceived mental and physical health as well as on self-worth and relationships of residential seniors than the peer-group setting. Quality of life in elderly institutionalized individuals is a complex construct based on internal and external factors. Physical health, social support and personality traits play an important role in how quality of life is perceived [155]. But quality of life also strongly relates to whether a person is recognized as an individual and by doing meaningful things [156]. I am not able to discern whether the improvement in physical functioning was the catalyst for psychosocial improvements or the other way around. I am, nevertheless, able to make an assumption as to how the presence of children positively affects multiple dimensions of said construct. The intergenerational and peer-group both showed physical improvements, but the intergenerational one exceeded the peer-group in total scores of both SF-36 and AQoL-8, allowing the conclusion that, additionally to physical improvements, the intergenerational setting allows synergies between generations to positively impact psychosocial wellbeing. Considering the physical health-effects and the ability to satisfy social needs of seniors, the intergenerational setting is a feasible exercise setting for residential living facilities to improve the general health of their residents.

As stated in the introduction, intergenerational projects should always aim for the benefit of both generations without the exploitation of one. This study was able to design an intervention which provoked health-benefits in both generations, therefore proving the mutual benefit for both age groups. The data speaks for a complementary implementation of such exercise programs to the existing ones in preschools and senior homes.

7.3 Potential intergenerational mechanisms

The results of the study are especially impressive considering that the intervention comprised solely 25 training sessions, distributed weekly over a scholastic year, each lasting 45 minutes. Due to its content, it was possible to perform the same sessions in each intervention group. The macro-structure of the interventions divided the 25 sessions into 5 blocks comprising 5 sessions, each block alternating between a focus on locomotor or object control skills. The blocks were additionally planned around a theme (i.e., traveling and countries, circus, winter sports and spring activities) in order to engage children as well as seniors and provide topics for interactions and discussion between participants in all intervention arms. The intervention did not aim at high-intensity, nor did it focus on specific endurance or strength training, but instead focused on everyday movement patterns for each age group and numerous variations thereof, meeting the physical and social needs of both age groups.

7.3.1 Intergenerational mechanisms in children

The underlying causes of the different improvements in physical performance between the intervention groups were not examined in this study, as this goes beyond the scope of my thesis. Nonetheless, I can make certain assumptions in order to provide context for the interpretation of the results and future intergenerational exercise programs. In the intergenerational setting, children were paired with seniors for group activities and exercises. Hence, the children had to adapt to their partners in a more distinctive manner than when playing with same-aged partners. Many seniors performed the sessions seated in a chair and were therefore less mobile and slower than children. By playing with mostly chair-bound partners, children were urged to move in a more precise and controlled manner, all the while being highly aware of their surroundings. In order to keep the games ongoing, the children were compelled to be in constant motion, therefore being under constant, albeit low, load. These factors all might explain why the intergenerational children show largest improvements in gross motor skills, especially in locomotion, compared to the peer-group. In a peer-group setting, children are faster at retrieving badly aimed objects and the flow of the game can be upheld even if the children do not move themselves or the objects in a very precise and conscientious manner. Collisions between children occur often during play, and generally do not bear any consequences which would evoke a change in behavior or locomotion. The intergenerational setting, in contrast, might have directed the children to be more aware of themselves, their surroundings, and how they interacted between each other. This potential mechanism is supported by previous examinations in the field of intergenerational projects. A German project named "Begegnungen" was able to show how regular encounters and shared social activities between children and seniors (i.e. handcraft work, baking, singing etc.) increased children's ability to change perspective as well as their empathy and sense of self-worth [76]. Although I did not measure explicit increases in social-emotional skills compared to the other study arms, the children's ability to exercise and practice their social skills were challenged more during the exercise sessions, which ultimately manifests itself in their physical performance. The improvements in gross motor skills might be the result of an increase in the consciousness of their movement patterns, manifested by better motor control and coordination. Studies have shown that higher coordination levels are linked to higher strength and power parameters [157]. Evidence additionally suggests that increases in muscular strength, especially during childhood, are the result of neuromuscular learning and neural adaptations [158]. This might explain, in addition to natural biological processes, the improvements in handgrip strength of the intergenerational children, as strengthening exercises were not explicitly incorporated in the sessions. Despite these possible explanations, the mechanisms behind the improvements are as yet not understood and should be topic of further studies.

7.3.2 Intergenerational mechanisms in seniors

Seniors in both intervention arms showed highly relevant physical improvements. According to the literature, participation in exercise programs declines with age and exercise programs need to fulfill certain environmental, personal and social criteria in order for participants to commit and adhere [159]. The intervention program was able to fulfill the necessary characteristics, confirming how social aspects elicited by a group setting, independently of constellation, are fundamental for long-term participation. In order to improve physical functioning in age, meeting social needs of seniors are a prerequisite. The results show that intergenerational seniors improved everyday functional parameters such as gait speed and total SPPB score more than peer-group training while high-power movements were comparable in both intervention groups. I derive these effects from the fact that in the intergenerational group, seniors received more incentive to perform dynamic walking movements and were forced multiple times to stand up and sit back down during the sessions in order to support the children in the given motor tasks. Even while being limited to a seated position, seniors were engaged in a manner which kept their body in constant motion. This adaptation of movements to a seated position kept the seniors as well as their partners engaged in the games, stimulated body awareness and disrupted sedentary time. The presence of children engaged the seniors beyond the given tasks, which could, in part, explain the physical improvements. As mentioned before, seniors in residential care tend to extremely high inactivity [43]. Many studies have shown how sedentary time is detrimental to health as it is strongly associated to cardio-metabolic and inflammatory biomarkers [160]. This study proves how even very low doses of exercise elicit a physical adaptation in highly inactive populations. Exercise programs, such as the intergenerational setting, which focus not so much on increasing moderate-to-vigorous activity but moreover aim at decreasing sedentary time, possess great potential in residential care settings. A weekly intergenerational program along the lines of the examined one could almost double weekly active time of seniors living in nursing homes. Exercise programs in residential care, therefore, should aim at breaking up and reducing sedentary time of residents, and the intergenerational setting seems to be a suitable option.

The intergenerational seniors showed small to moderate but overall positive tendencies also in quality of life. Compared to the control group, which showed moderate decreases over all measured dimensions, this is a highly relevant aspect which should not be overlooked. Mental and physical health go hand in hand in old age, and the interactions between the two dimensions should be targets of exercise interventions. Studies were able to show how isolation and neglect bring forth a cascade of mental and physical illnesses in old age [156, 161]. The presence and cooperation with children might act as catalysts for action in residential seniors in order to engage them in a way that positively affects not only their physical but also their mental health. This potential mechanism is supported by the "Begegnungen" project which measured increases in quality of life as well as active interest in activities in seniors with dementia through intergenerational exposure in artistic and social settings [76]. The *Generations on the Move Study* was able to prove that an intergenerational exercise setting can influence both aspects of health in residential seniors and thereby complements the literature on intergenerational projects.

7.4 Practical applications and considerations

The *Generations on the Move Study* speaks in favor of incorporating intergenerational exercise sessions in preschools and senior homes. In order for such programs to be effective, certain crucial criteria must be taken into account.

We examined healthy children and, on average, the intergenerational group did not differ in any measured physical parameters from the other groups. We did find that the average score for social-emotional competence was lower in the intergenerational group than in the other groups at baseline, and that this gap closed after the intervention. Therefore, healthy preschoolers showing no apparent deficits in motor development with slightly lower than average social-emotional skills are suitable for such programs and can profit on a physical and social level. Whether the setting brings forth extensive social-emotional improvements in children with already pronounced skillsets needs to be further investigated. We advise intergenerational exercise as a complementary or supplementary tool for children to engage in. As previously mentioned and proven, children possess a high variety of needs which can be fulfilled by the intergenerational setting. Nevertheless, there are other important health-dimensions of childhood development which were not measured in this study, such as aerobic fitness, mobility, speed and agility [8]. The importance of physical activity in a peer setting is still very important and should not be reduced or undermined by our results. Activity guidelines recommend at least 60 minutes of moderate-to-vigorous physical activity per day for children, and our study design did not entirely fulfill these recommendations [162]. The intergenerational setting should therefore not replace exercise sessions in kindergartens, but should be incorporated additionally to the physical education curriculum. Additionally, the option of applying the intergenerational approach for children with less developed motor skills can be postulated in order to specifically improve recognized deficits and purposefully support their development.

The seniors in the intergenerational groups, on the other hand, showed slightly lower than average values in all measured parameters, both in physical performance and psychosocial well-being. As the intervention was able to improve both dimensions of health, we recommend the intergenerational approach as an effective option to engage seniors in physically and psychosocially beneficial activities. It should, therefore, be incorporated in nursing homes which wish to maintain and improve physical functionality, psychosocial profile and quality of life of their residents. Seniors who show high inactivity and low engagement in other activities and who also enjoy and tolerate being surrounded by children could especially profit from such sessions.

For any intergenerational approach, the mutual benefit for both generations must be ensured. Therefore, future shared activities must respect physical predispositions and social needs of both, without exploiting one for the benefit of the other. This is especially important for the implementation of similar programs as the participants show large heterogeneity, both on an inter- and intra-generational level. Children show age-dependent differences in physical performance and motor competence, whereby the development does not increase in a linear manner. Also social-emotional aptitude differs between age groups, and children's behavior and actions strongly depend on these skill-sets. All these factors need to be considered when planning exercise sessions in order to support childhood development on an individual level. A factor which also needs to be considered is the fact that only healthy children, with no pronounced developmental difficulties or disorders or health-related risk were included in this study. The intervention and its results must therefore be applied and generalized with reservations to different populations, i.e., cognitively challenged or obese children.

The range of intra-generational differences are most evident in the senior population. Senior participants ranged from 72 to 101 years of age at baseline and, in line with this large age difference, I found different stages of independence, physical limitations as well as mental health and psychosocial wellbeing in the included study population. Given their living situation, all seniors had lost some level of independence as they all lived in a residential care facility. The extent of their physical limitations and functionality nevertheless differed strongly between individuals and were not dependent on age. Therefore, physical functioning more than age need to be considered and respected when incorporating similar programs, and the content and intensity of the exercise program needs to be adjusted and tailored to individual predispositions.

In order to meet these inter- and intra-generational differences properly, specialized instructors are key components of intergenerational programs. Instructors should not only have vast and specific knowledge in training and sport science, but must also be able to engage participants in a motivational and safe environment. Therefore, a training course and coaching experience prior to initiating programs should be mandatory for future instructors. For such settings to flourish and become self-sustainable, the active involvement of the partnering institutions, namely kindergartens and nursing homes, are crucial. Educating kindergarten teachers as well as nursing staff by filling gaps in knowledge and providing them with the necessary tools to take over the planning and execution of the lessons would allow them to incorporate such intergenerational activities in their respective curriculums and programs without additional resources.

7.5 Strengths and limitations

The presented study is the first controlled trial examining the intergenerational exercise setting. The five-armed study design enabled the comparison of the intergenerational constellation not only with an inactive control condition, but also to peer-group exercise, therefore providing valuable information in how to interpret the data. An additional strength lies in the incorporation of not only physical health outcomes, but also the social-emotional dimension as well as psychosocial wellbeing and quality of life. This enabled a more global assessment of health, especially in old age.

A further strength of the study lies in the real-life applicability of the intervention. More than one session per week is hardly applicable unless the rigid structures and given schedules in preschools and residential care are loosened. Despite the low dose, we were able to measure beneficial effects. A more frequent and higher dosage might have shown larger effects, and should be considered in further studies. The weekly sessions, nevertheless, reflect real-life situation and the data can be regarded as representative for such exercise programs in the chosen populations. There are further aspects regarding the exercise dose which one needs to consider when interpreting the findings. The duration of the sessions were limited at 45 minutes, which do not fulfill the minimum daily activity guidelines for children [162]. Children performed other forms of activities throughout the week in the kindergartens, and the content of these activities might have diverged between institutions and therefore influenced their development differently. Additionally, the content of the intervention mostly corresponded to light to moderate, but not to vigorous activity. Therefore, the findings are to be regarded as highly specific to the setting, i.e. preschool children and residential seniors who can profit from such low-intensity, motor skill-based approaches. If such intergenerational sessions are performed with older children and more independent seniors at higher intensities and with more complex movements, the content of the exercise sessions should be adapted accordingly.

Due to the complex setting in kindergartens and senior homes, the participants could not be systematically cluster-randomized as the kindergartens were only able to participate as an entity. Group allocation had to be performed prior to the pre-measurements due to the complex organizational procedures, as kindergartens had to be in geographical vicinity to their partnering residence homes. This led to slight differences in social-emotional skills between study arms at baseline. These differences might also be attributed to the nature of the assessment method, in which kindergarten teachers rated children's competence based on their own observations. Also, intergenerational seniors were slightly older in mean age than the seniors in the other groups. Despite these baseline differences, I was able to consider certain defined criteria when allocating the study arms. Kindergartens were assigned based on a) number of children; b) age of children; c) migration background of children and; d) proximity to senior residence homes. Residence homes were allocated based on a) number of senior participants; b) age of senior participants and; c) geographical location. Despite these limitations, baseline data between the age groups was balanced in most measured parameters. The number of participants per group is relatively low due to the number of study arms, the strict exclusion criteria for senior participants as well as dropouts. Furthermore, most senior participants were female and individuals who enjoy company of children and did not have any cognitive impairments. Therefore, one must be cautious in generalizing and applying the information, particularly to older men or seniors showing cognitive disorders such as Alzheimer's or dementia. Moreover, all children were healthy and did not show any psychomotor disorders. How such an intervention affects at-risk children, or children manifesting developmental issues, remains to be determined. Nevertheless, this study reveals important information on the mutual benefits of two age groups in a previously unexplored field and provides a solid foundation for future studies in the field of intergenerational exercise.

7.6 Outlook and future studies

As discussed in chapter 7.3, the mechanisms and synergies of the intergenerational setting are not understood yet. Our study provides evidence of physical as well as psychosocial improvements, but the underlying mechanisms could not be explored as it was not the aim of the research project. The analysis of interactions, movement patterns and behavior during intergenerational exposure could be a future research field. Such observational studies could fill the exposed gap of understanding intergenerational synergies and how they relate to our measured effects.

Considering the separation of social structures in our modern society, programs that enable contact between non-biologically linked children and elderly might have long-term and groundbreaking consequences. Intergenerational intolerance and polarization have been described in many aspects of society, especially in the workplace [67, 163]. By exposing children at an early age to positive interactions with the elderly, whereby they share activities which satisfy needs of both age groups, might provide them with necessary skillsets to reduce such stereotypes and negative views of older generations. Long-term or follow-up studies examining such social factors could provide more in-depth information and knowledge on the effects of such programs. Additionally, tracking studies on the activity and exercise behavior could provide insight on how early promotion of gross motor skills impacts lifelong activity and physical health.

Furthermore, the long-term effects of regular exercise in the elderly should be topic of investigation. Such data would provide insight into the impact of exercise in the aging process, as such old populations are rarely examined. Additionally, such data could supply knowledge on how to improve and positively influence quality of life and mental health in nursing homes and residential care.

An additional possible research field could examine different populations of seniors and children than the ones examined in this study. Possible study targets could be inactive elderly close to losing physical independence, in order to assess whether intergenerational exercise could increase independence and delay institutionalization. The presented data shows that children trigger inactive seniors to reduce sedentary time. By engaging seniors on the verge of institutionalization in physical activities might support the maintenance if not the improvement of their physical health, therefore increasing independence and delaying institutionalization. Children who manifest gross motor or social difficulties could also be a possible study population in order to assess whether the intergenerational setting can reduce such deficits by providing them with a non-competitive, supportive and appropriately paced environment. A possible study field could also contemplate studies with orphaned children to examine the impact of positive exposure to elderly individuals.

7.7 Conclusion

Intergenerational exercise programs possess great potential in bringing together different generations in common and shared activity, while positively affecting physical and psychosocial health of both. Children are supported especially in their gross motor skill development while seniors are able to maintain and improve their physical health and everyday functionality while ameliorating their psychosocial health profile.

The intergenerational exercise setting, therefore, is a very promising strategy to promote physical performance parameters essential for lifelong fitness and health in children while simultaneously challenging their social-emotional learning skills and increasing exposure to older generations. The maintenance and, more importantly, the improvements in physical health in seniors are very promising, speaking in favor of this setting, especially in combination with the improvements in mental health and quality of life.

For preschools, such exercise sessions could accompany their curriculum and may be implemented as complementary to other specific exercise programs. In nursing homes and residential care, intergenerational exercise programs should also be implemented with the goal of increasing mental wellbeing and physical functionality. Such an exercise program might be able to decrease sedentary time and break up the isolation in nursing homes, especially for very inactive and otherwise solitary individuals. Opportunities for such exercise programs should be facilitated and supported.

Future fields of research could examine the mechanisms and synergies between the generations in intergenerational settings, the long-term effects of such programs on physical, social as well as mental health and wellbeing, as well as applying the approach to different populations of children and seniors.

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Appendix A: Contributors

The author of the presented dissertation led the "*Generations on the Move Study: intergenerational exercise and health promotion*", from its conception, to its execution and the resulting publications. She was responsible for the study design, in researching and deciding on the applied methods and organizing the instruments, writing the ethics proposal, planning and organizing the intervention, setting up and executing an internal training program for the preparation of the study staff, the recruitment of participating institutions and the respective children and seniors, coordinating and planning the measurement phases, conducting and overseeing the intervention and the students, collecting data and conducting statistical analyses, supervising students in their Bachelor and Master thesis, writing the manuscripts and finally submitting and publishing the papers as first author. In addition to the author, four experienced scientists contributed as supervisors to the success of the research project. Their contributions are specified below.

PD. Dr. Oliver Faude: Is the first supervisor and supported the statistical analyses and the writing of the manuscripts. He also provided support in strategic decisions regarding the study as well as the publications.

Prof. Dr. Henner Hanssen: Is the second supervisor and provided his expertise in the study design and set up of study procedures. He also critically revised all final drafts of the publications.

Prof. Dr. Lars Donath: Participated in the study design, advised the selection of outcome measures and critically reviewed the ethics proposal. He furthermore revised all final drafts of the publications.

Prof. Dr. Lukas Zahner: Generated the initial idea for the study and participated in the study design. He also provided a valuable contact in the education department in order to reach kindergartens in Basel-Stadt.

A large team of sports science students was integrated in the project as part of their Master or Bachelor theses and for learning contracts. They performed measurements and supported data collection as well as being instructors in the intervention. The following students were involved in the measurements and / or the intervention: **Dominique Hohle, Sean Wartmann, Céline Lang, Andrea Roffler, Natascha Savanovic, Chantal Zehnder, Kerstin Rupf, Samuel Meyer, Jessica Preiss, Nora Degonda, Jan-Niklas Kreppke, Lukas Nebiker, Paul Ritsche, Nik Hagenbuch and Milan Bertschinger**.

Additionally to University staff, a number of kindergarten teachers and nursing home therapists supported and helped organize the measurements and intervention. The following kindergarten teachers cooperated: **Dominique Spampinato & Claudia Dürr, Melina Friedrich, Silvia Zinniker & Aline Rüschoff, Claudia Weill & Susanne Züger, Silvia Kopp, Sabine Kammer & Judith Ruflin**. From the senior homes the following individuals helped and supported the study: **Isabelle Büttiker & Loes Lamers, Cornelia Braun, Simone Leitner & Silvia Hofer**.

Appendix B: Curriculum Vitae

Name	Alice Minghetti
E-Mail	alice.minghetti@unibas.ch

Education and professional degrees

Since August 2018	Doctoral Candidate, *Department of Sport, Exercise and Health, University of Basel*
09.2014-12.2016	Master of Science in Sports Science with Italian Language and Literature, *University of Basel*
09.2013-09.2014	Exchange study year, *Univeristà degli Studi Rome Tre*
09.2010-09.2013	Bachelor of Science in Sports Science with Italian Language and Literature, *University of Basel*
07.2010	Matura, *Kantonsschule Wettingen*

Professional background

Since May 2021	Researcher (20%), *University Children's Hospital beider Basel*
	Project leader in the "Functional exercise intervention with adolescents with cerebral palsy" research study
Since February 2017	Stiftung Hopp-la (50%)
	Project evaluation, scientific steering and strategical orientation
Since March 2019	CrossFit Kids Instructor, *CrossFit Basel*
	Initiator and project leader of an exercise program for children and adolescents
Since December 2015	CrossFit Coach, *CrossFit Basel*
08.2016-12.2017	Assistant, *Department of Sport, Exercise and Health, University of Basel*
	Division Movement and Training Science and Sportsmedicine Data collection, data analysis, literature research, writing of manuscripts for publication, supervision of students and study coordinator (MigSpo Study; Depression & Sport Study).
09.2015-06.2016	Swimming Instructor, Technique Course, *Unisport Basel*

09.2014-04.2016	Swimming Instructor, Swim Talent Academy (STA), *Schwimmverein beider Basel*
02.2011-06.2013 09.2014-12.2016	Tutorial assistant, *Department of Sport, Exercise and Health, University of Basel* Practical discipline Swimming 1&2 (Bachelor Curriculum)

Publications

PhD relevant	Minghetti, A., Donath, L., Zahner, L., Hanssen, H., & Faude, O. (2021). Beneficial effects of an intergenerational exercise intervention on health-related physical and psychosocial outcomes in Swiss preschool children and residential seniors: A clinical trial. *PeerJ, 9*, e11292.
	Minghetti, A., Donath, L., Hanssen, H., Roth, R., Lichtenstein, E., Zahner, L., Faude, O. (2021). Physical performance, cardiovascular health and psychosocial wellbeing in elderly compared to oldest-old residential seniors. Under review in *Frontiers in Medicine.*
	Minghetti, A., Lichtenstein, E., Donath, L., Wartmann, S., Hanssen, H., Faude, O. (2021). A cross-sectional analysis of motor competence and social-emotional skills by gender and age in preschoolers. Under review in *Child: Care, Health & Development.*
	Minghetti, A., Faude, O., Donath, L., Hanssen, H. (2021). Effects of a motor skill-based exercise intervention on cardiovascular health in healthy preschoolers. Under review in *Child: Care, Health & Development.*
Other publications	Minghetti, A., Faude, O., Hanssen, H., Zahner, L., Gerber, M., Donath, L. (2018). Sprint interval training substantially reduces depressive symptoms in major depressive disorder (MDD): A randomized controlled trial. *Psychiatry Research*, 265: p. 292-297.
	Hanssen, H., Minghetti, A., Magon, S., Rossmeissl, A., Papadopoulou, A., Klenk, C., Schmidt-Trucksäss, A., Faude, O., Zahner, L., Sprenger, T., Donath, L. (2017). Superior Effects of High-Intensity Interval Training vs. Moderate Continuous Training on Arterial Stiffness in Episodic Migraine: A Randomized Controlled Trial. *Frontiers in Physiology*, 8, 1086.
	Hanssen, H., Minghetti, A., Magon, S., Rossmeissl, A., Rasenack, M., Papadopoulou, A., Klenk, C., Faude, O., Zahner, L., Sprenger, T., Donath, L. (2017). Effects of different endurance exercise modalities on migraine days and cerebrovascular health in episodic migraineurs: A randomized controlled trial. *Scandinavian Journal of Medicine and Science in Sports*, 28(3).

Hanssen, H., Minghetti, A., Faude, O., Schmidt-Trucksäss, A., Zahner, L., Beck, J., Donath, L. (2018). Effects of Endurance Exercise Modalities on Arterial Stiffness in Patients Suffering from Unipolar Depression: A Randomized Controlled Trial. *Frontiers in Psychiatry*, 8(311).

Nebiker, L., Lichtenstein, E., Minghetti, A., Zahner, L., Gerber, M., Faude, O., Donath, L. (2018). Moderating Effects of Exercise Duration and Intensity in Neuromuscular vs. Endurance Exercise Interventions for the Treatment of Depression: A Meta-Analytical Review. *Frontiers in Psychiatry*, 9: p. 305.

Hanssen, H., Minghetti, A., Faude, O., Schmidt-Trucksäss, A., Zahner, L., Beck, J., Donath, L. (2018). Effects of different endurance exercise modalities on retinal vessel diameters in unipolar depression. *Microvascular Research*, 120: p. 111-116.

Gerber, M., Minghetti, A., Beck, J., Zahner, L., Donath, L. (2019). Is improved fitness following a 12-week exercise program associated with decreased symptom severity, better wellbeing, and fewer sleep complaints in patients with major depressive disorders? A secondary analysis of a randomized controlled trial. *Journal of Psychiatric Research*, 113:58-64.

Gerber, M., Minghetti, A., Beck, J., Zahner, L., & Donath, L. (2018). Sprint interval training and continuous aerobic exercise training have similar effects on exercise motivation and affective responses to exercise in patients with major depressive disorders: a randomized controlled trial. *Frontiers in Psychiatry*, 9, 694.

Teaching experience

2020 & 2021	Lecturer in the Advanced Study Course *Bewegungsförderung im Alter (BefiA)*
HS 2020	*Funktionelle Anatomie* Five practical units (Bachelor)
FS 2020 & FS 2021	*Trainingsplanung, -durchführun und –auswertung* Two practical units (Bachelor)
FS 2019, HS 2019, FS 2020, HS 2020	*Trainingswissenschaft* Seven practical and theoretical units (Bachelor)
FS 2019, FS 2020, FS 2021	*Erhaltung der körperlichen Leistungsfähigkeit in der zweiten Lebenshälfte* Five lectures (Master)

FS 2019, FS 2020	*Training in Fitness und Wellnesseinrichtungen* Three practical and theoretical units (Bachelor)
HS 2018, HS 2019, HS 2020	*Entwicklung der körperlichen Leistungsfähigkeit in der ersten Lebenshälfte* Seven lectures (Master)
HS 2018 – HS 2021	*Funktionelle Anatomie* Assistant and examiner in oral exams (Bachelor)

Supervision of scientific projects

Master Thesis	Dominique Hohle, Lorenz Meier, Laura Altenbach, Lyne Anderrüti.
Bachelor Thesis	Sean Wartmann, Chantal Zehnder, Natascha Savanovic, Kerstin Rupf, Samuel Egli, Annina Knecht, Céline Lang, Nadja Kilchenmann, Nina Stam, Fabienne Studer.

Conference Contributions

Oral presentations	European College of Sport Science (ECSS), 25th annual conference 2020, *Sevilla*. Abstract accepted for oral presentation but cancelled due to Covid-19.
	Swiss Society of Sport Science (SGS), 12th annual conference 2020, *Basel*
	Swiss Society of Sport Science (SGS), 11th annual conference 2019, *Fribourg*
	Swiss Society of Sport Science (SGS), 9th annual conference 2017, *Zürich*
	City Health International (CHI), 6th annual conference 2017, *Basel*
Poster Presentations	Tag der Klinischen Forschung, 2017, *Basel*
	International Headache Convention (IHC), 18th convention of the International Headache Society, 2017, *Vancouver*

Graduate Education

Course	Institution	ECTS
Text- und Kulturanalyse mit R	University of Basel	3
Qualitative Data Analysis: Analyzing Text and Talk	University of Basel	3
Seminar: Statistik I – Theorie und Anwendung	University of Basel	3
Seminar: Statistik II – Theorie und Anwendung	University of Basel	3

Teaching my first course	University of Basel	1
Writing a research paper in 12 weeks or less	University of Basel	3
Sterblichkeit- Statistik, Modellierung und Prognose	University of Basel	3
Total ECTS		19