



# Indentification of Types and Levels of Physical Activity Throughout Childhood for Healthy Growth and Development

*Cambridge Centre for Sport and Exercise Sciences on behalf of Start-Rite Shoes Ltd.*

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# Executive Summary

The purpose of this literature review is to draw together the current knowledge and guidelines for physical activity in children. Where possible it aims to identify the type, frequency and intensity of exercise recommended in three specific age groups, 0 - 5 years, 6 - 10 years and 11-16 years old.

In children aged 0-5 years old there are a number of clear phases of development. For infants from 0-1 year old, robust evidence for 30 minutes of “tummy time” or prone play and infant swimming lessons clearly emerges from the research, with evidence suggesting that baby walkers offer no additional benefit to helping children learn to walk. More time spent outside and with older children at this age was also positively associated with better motor control skills at 5 years of age. For infants from 1-3 years old, regular freedom to play and playing with other children were also shown to improve locomotor and object control skills at 5 years old. Emerging evidence shows that for infants from 2-5 years old introduction to organised sports may have a positive influence psychologically, emotionally and socially.

In children as young 6 years old, physical activity has been shown to have positive mental health benefits when the guideline 60 minutes per day on average across a week, with three bouts of vigorous activity, are met. It is particularly striking that in studies of children where activity has been objectively measured less than 10% of children are meeting these guidelines, with parental estimates of childrens activities being shown to grossly over estimate their activity particularly in terms of the intensity of the activity. School play times, organised sports and activities which include family members have been suggested to be key to increasing the levels of physical activity with a particular focus on activities that take place at weekends and in school holidays recommended.

In adolescents, those aged 10-15 years of age, it is clear that PE lessons alone only provide the minimum amount of recommended physical activity. There is a clear need to increase physical activity levels in this age group, particularly amongst

girls, with organised sporting activities suggested to be the best approach for achieving this.

In all age groups, meeting the recommended levels of moderate to vigorous physical activity set out in the government guidelines were positively associated with numerous health and development benefits, such as increased bone mineral density, reduced risk of obesity in later life, improved motor skill acquisition and increased fitness levels. It is also apparent that there is no upper limit to the amount of physical activity undertaken in children as long as the level of activity is progressively attained. Across all age groups it is accepted that positive experiences of physical activity in childhood has lifelong positive effects on health and wellbeing.

# Introduction

Government and research guidelines for physical activity in childhood tend towards only reporting the general amount of activity children should participate in. The type, intensity and frequency of activity is often only vaguely reported. In some cases, the reported activity levels are generically reported for all children and young people from 0 to 18 years of age.

It is therefore the aim of this report to investigate further the type, intensity and frequency of activities which are recommended during childhood. In line with the interests of Start-Rite to be able to provide scientifically backed advice to parents, and to complement their on-going relationship with the Daily Mile, this report focuses on three main age categories:

0 - 5 years

6 - 10 years

11-16 years

Broadly speaking these ages represent infants & toddlers (0 - 5 years), children (6 - 10 years) and adolescents (11 - 16 years). It is important to note that these age ranges define generic periods of a child's growth and there may be significant differences between individuals.

Physical activity is recognised as having positive health benefits, such as developing and maintaining physical and mental function across all ages. It is especially important during maturation in the first 2 decades of life for healthy growth and development. The UK Chief Medical Officers' Physical Activity

Guidelines<sup>1</sup> highlight that physical activity during this time is declining, yet the understanding of the health benefits of physical activity are becoming more compelling. There is no minimum amount of activity required for there to be health benefits, however there does appear to be a positive relationship between more physical activity and greater health benefits, as well as greater intensity activity providing a broader range of health benefits. The health benefits associated with physical activity are most noticeable in those with the lowest activity levels, that is those completing less than 30 minutes of activity per week. These guidelines draw upon a wide range of scientific research and expert opinions, however they do not report the types of activity that are being undertaken.

This report draws upon knowledge from published research, identified using a systematic literature search approach, national governing body and government guidelines to identify where possible the types, frequency and duration of physical activity the above-mentioned age groups should be recommended to participate in and the health benefits to which this is beneficial.

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<sup>1</sup> <https://www.gov.uk/government/publications/physical-activity-guidelines-uk-chief-medical-officers-report>

# 0 - 5 years

In the first five years of life, humans go through dramatic changes in their physical, social and cognitive skills. Born “motorically challenged”<sup>1</sup>, by the time they start school children will be able to walk, run, jump, skip, hop, as well as manipulate objects such as balls, bats, forks and pens. They will have increased their body mass by 500% and learned a new language. With so much change occurring over this period it can be difficult to identify what activities best facilitate this rapid development. However, this report will attempt to summarise the current literature in this vein. To do so, we start by discussing the physical end goals of the preschool period (3-5 years). Subsequently, we will review research detailing what activities help infants (0-1 year) and toddlers (1-3 years) achieve these end goals.

The UK Government guidelines for physical activity (PA) for children aged 3-4 years is to engage in 3 hours of PA per day including at least 2 hours of moderate-to-vigorous physical activity (MVPA)<sup>2</sup>. The research underpinning the importance of PA in this age group has grown considerably since the previous guidelines were released in 2011. Increased PA in this age group has been found to have positive relationship with cardiometabolic health indicators<sup>3</sup> and bone mineral density<sup>4</sup>, as well as a negative relationship with obesity<sup>3</sup>. However, the types of physical activity that are most beneficial are less clear.

Recent studies have focussed on the relationship between motor skill competence (MSC) and time spent doing PA. MSC can be defined as person’s movement coordination quality when performing different motor skills, ranging on a continuum from gross to fine motor skills<sup>5</sup>. A variety of tests have been used to assess this, but broadly they all cover similar skills (table 1). Although some of these tests focus on the quality of the movement, it has been suggested that the outcome of the movement may be more useful.

Table 1. Summary of basic motor skills assessed in motor skill competence tests

Locomotion	Object Control	Balance (control of CoM)
Crawling	Striking	Sitting unsupported
Walking	Catching	Standing
Running	Rolling	Standing on one leg
Hopping	Kicking	
Jumping		

A number of cross-sectional studies have found that children with higher MSC also spent more time doing MVPA <sup>6-9</sup>. However, as these studies were merely reporting correlations, the direction of this relationship is unclear, i.e. does increased MVPA improve MSC, or does increased MSC give children confidence to spend more time doing MVPA?

Studies investigating the effect of MSC interventions on PA have been mixed. Alhassan et al., (2012) found that a locomotor skills-based intervention reduced sedentary behaviour in 3-5 year olds. Conversely, Bellows et al. (2013) found that improvements in gross motor skills did not come with concomitant increases in PA levels. Stodden et al. (2008) argue that the strength of the relationship between MSC and levels of PA increases through early to late childhood and into adolescence, suggesting Bellows et al. (2013) might have found an increase in PA over a longer time frame as result of their intervention. Addressing the opposite causality, studies using interventions to increase PA have not found immediate improvements in MSC <sup>12,13</sup>. It may be as previously covered, these effects strengthen during childhood and into adolescence, or, as Venetsanou, Kambas and



Giannakidou, (2015) suggests, PA alone does not improve MSC, and that organised PA is required.

Regardless of the direction of causality, MSC itself is positively related to a variety of health outcomes, and as suggested this relationship may strength overtime <sup>9</sup>. Developing good motor skills in this pre-school, 3-5 years age range may well lead to greater adherence to PA in later life <sup>15</sup>. However, in order to refine these motor skills in the pre-school age group, children must first learn how to execute these skills to a basic level. While some research exists involving the motor skills of pre-school children, research investigating younger age groups is inevitably more scarce and lower quality. This is often due to the ethical issues of conducting randomised interventions on children in these formative months and years. However, some research - often cross-sectional - does exist on very specific methods of motor skill learning.

In infants (0-1 year), one area that has attracted a lot of attention is the idea of “tummy time” or prone play. Since 1992, parents have been advised to put their infants on their backs while sleeping due to an association with sudden infant death syndrome <sup>16</sup>. However, researchers subsequently noted that the switch to supine sleeping was associated with delays in reaching some motor skill milestones, particularly rolling, crawling, creeping, sitting tripod and pulling themselves up to standing <sup>17</sup>. However, a number of recent studies have shown that allowing infants to play in a prone position, otherwise known as “tummy time”, mitigates this developmental delay <sup>18-22</sup>. Subsequently, the new UK Government Guidelines for PA advocate at least 30 minutes of “tummy time” spread throughout each day.

Another area that has received some attention is the use of baby walkers. Baby walkers are devices on wheels that support the infant in an upright position, allowing infants without the required stability to locomote. It has been suggested since the late 1970’s that the use of baby walkers can delay or negatively affect the gait of toddlers <sup>23,24</sup>. Some studies have found that walking age can be delayed by between 11 and 34 days <sup>25,26</sup>, while others have found no significant delay <sup>23,24,27,28</sup>. Studies have also suggested that there may be a difference in the gait pattern between toddlers who used baby walkers and those who did not <sup>23,26,27</sup>.

These include changes in gait temporospatial parameters (e.g. stride time, gait velocity, stride length), joint ranges of motion and muscle activation. Although some of these studies suggest that the effects diminish over time <sup>16</sup>, it is unclear what knock-on effect these differences might have in later childhood. Overall, it is still an open question whether baby walkers are detrimental to motor development, but it does appear clear that the use of baby walkers does not hasten the learning process, as manufacturers may suggest.

Another promising area of research is in infant swimming lessons. Three relatively recent studies have found that swimming lesson for infants improved physical health and motor skill, in particular grasping and standing balance <sup>29-31</sup>. The suggestion being that changes in orientation increase vestibular stimulation and improve balance, which help with prehension when reaching for balls and the side bar.

Research concerning other equipment or activities is less forthcoming. However, there are more general recommendations regarding how the home environment can influence a child's gross motor skills. Barnett et al. (2019) conducted a prospective study of 259 infants, questioned on the home environment, child behaviour, parental behaviour and maternal beliefs at 4, 9 and 19 months, and 3.5 and 5 years. The children's MSC was then tested at 5 years of age. At 4 months old, time spent with older children (26-343 mins/week) was positively associated with better object control skills at 5 years. At 9 months, time spent outside (34-257 mins/week) was positively associated with better locomotor skills at 5 years. It is also suggested that at 9 months, having a range of (average of 6) age appropriate toys helped with locomotor and object control skills at 5 years. Therefore, while some specific examples of beneficial activities are useful, it is clearly also important to setup the home environment in a way that allows children to explore and master new motor skills independently.

As infants progress to walking, there are both differences and similarities in the most beneficial types of physical activity. It has been suggested that 1-3 year age group children partake in predominantly "exercise play" <sup>33,34</sup>. Exercise play in this context can be defined as gross motor movements in the context of play. This can

be solitary, with parents or peers, but is always vigorous in its intensity<sup>33</sup>. The prospective study by Barnett et al. (2019) also investigated this age range. At 19 months, children who had between 73 and 206 mins/week free to move about without restraint had significantly better locomotor and object control skills. Also, at 19 months, time spent playing with other children (10-30 mins/week) was positively associated with better object control skills. Whereas, at 3.5 years, time spent with older children was positively associated with improved locomotor skills but appeared to have a ceiling effect with a time range of 50-420mins/week. Finally, rather than the number of available toys, at 3.5 years, the frequency of use of the toys (daily use) was positively associated with object control skill. These findings appear to support the concept of “exercise play” as a main source of physical activity to promote MSC.

While “exercise play” could be seen as the predominant source of physical activity, it has also been suggested that organised sport may hold some benefit to toddlers and pre-schoolers<sup>35</sup>. As previously mentioned, undirected physical activity alone may not be sufficient to improve MSC<sup>14</sup>. Although limited, there is emerging evidence that organised sports can be seen as a positive influence on 2-5 year old children, psychologically, emotionally and socially<sup>35</sup>.

## Summary

The changes that occur over the infant, toddler and preschool years, make it highly important period. In order to prepare for and encourage the adherence to physical activity of their late childhood and adolescence, children first must develop the array of motor skills necessary to perform physical activity. Motor skills categories include locomotion, object control and balance. Competence in these motor skills by the age of 3-5 years has been shown to be positively related key health markers and adherence to physical activity.

In infancy (0-1 years), some specific activity-based recommendation can be made such as 30 mins/day total “tummy time” play, limiting the use of baby walkers and participating in baby swimming lessons. Some more general environmental

recommendations can also be made, such as spending at least 34-257 mins/week playing outside, at least 26-343 mins/week playing with older children, and having on average 6 age-appropriate toys or equipment that encourage object control and locomotion for varied stimulation.

Once walking, toddlers (1-3.5 years) should partake in predominantly “exercise play” - vigorous, gross motor movements at play. This should include 73-206 mins/week of free play without restraints, 50-420 mins/week play with older children, and daily use of age appropriate toys. These have all been found to have positive associations with motor skills at age 5. In addition to “exercise play”, it has also been suggested that organised sport has a positive influence on motor skill competence, and psychologically, emotionally and socially. Overall, across all age groups, ensuring that the child has the freedom to play and a variety of stimulation - both organised and unstructured - will allow the child to develop a well-rounded set of motor skills, and subsequently assist in adherence to physical activity in later childhood and adolescence.

## 6 - 10 years

Government guidelines state that from the age of 5+ children and young people should engage with an average of at least 60 minutes per day over a week of moderate to vigorous physical activity<sup>2</sup>. Moderate to vigorous physical activity is defined by the American College of Sports Medicine (ACSM) as activity which reaches 40-89% heart rate reserve<sup>36</sup>. Currently no evidence for specific numbers or durations of bouts is provided within the guidelines. The World Health Organisation suggests that 3 of these bouts should be vigorous activity which focuses on strengthening muscle and bone<sup>37</sup>. Children (aged 6 -10 years old) who meet the physical activity guidelines have been shown to have greater wellbeing scores<sup>38</sup>, with organised sport and vigorous physical activity been shown to be important for conferring wellbeing benefits including increased self-esteem and reduced reporting of depression<sup>39</sup>. In this age group the holistic benefits of physical activity are numerous and are suggested to have a life long impact on health and wellbeing.

Physical activity data in children at this age is generally collected using two methods, parental reports and activity monitoring devices such as accelerometers. Parental reports of children's activity levels have been shown to grossly over estimate children's activity levels. With this type of reporting suggesting that 68-72% of boys and 62-66% of girls at 10 years old are meeting the recommended physical activity guidelines. However, when compared to activity monitoring devices, which record duration and intensity of exercise via an accelerometer, it has been shown that as little as 5% of 11 year olds (5.1% boys and 0.4% of girls) meet the recommended levels of physical activity, with similar figures (3% of boys and 2% of girls) reported for 7 year olds<sup>38</sup>. With the rising concerns related to obesity it is not surprising that in primary school children as many as 25% of children were found to be obese<sup>40</sup>. Research such as this suggests that while parents may consider that their child is doing enough physical activity in terms of time, the intensity of activity may not be sufficient to meet the recommended guidelines. It has also been shown that the level of physical activity in children drops at weekends compared with their time spent at school<sup>41,42</sup> and that children

perform the majority of vigorous activities (such as running and jumping) during outdoor sports training<sup>43</sup>. This suggests that organised school activities and play times are key periods for physical activity for children and that there appears to be a need for more opportunities for organised activities to take place over weekend periods.

Children who are more physically active have been shown to be fitter and to carry the benefits of physical activity into later life. Fitness is trainable in children and higher levels of physical activity and fitness are associated with better metabolic health<sup>42,44</sup>. Training to improve fitness and strength at all ages has been shown to be effective at increasing measures of physical performance with a linear relationship between age and ability<sup>45</sup>. Girls have been shown to outperform boys between 7 to 12 years old in peak power output in tests conducted using cycling. Training to improve aerobic fitness (peak VO<sub>2</sub>) is not affected by age, with the biggest factor in the trainability shown to be the baseline fitness. That is, those with lowest fitness levels improve the fastest. These are independent of age effects showing that there is no optimum window of opportunity for children to develop aerobic fitness<sup>46</sup>. Prepubertal children have also been shown to make training induced strength gains from resistance training<sup>46</sup>, which has been shown to be advantageous in measures of physical performance<sup>47</sup>. This suggests that children who are not meeting the recommended levels of physical activity can quickly show improvements in both aerobic fitness and strength by engaging in training activities.

Evidence has also shown that physically active children have an increased proficiency in gross motor competence when compared to less active children<sup>48</sup>. This is the ability to complete gross motor skills which is a combination of fundamental movement skills (throwing, catching, running) stability skills (balancing) and object control (manipulative skills e.g. throwing). Exposure to different types of activity were shown to be important in developing gross motor competence<sup>48</sup>. Of note girls aged 5-8 years old showed potentially greater gross motor skills than boys<sup>48</sup> despite boys being shown to be more physically active than girls at all ages and more likely to take part in more vigorous physical activity<sup>49</sup>. It has been proposed that a positive spiral of engagement is created whereby

increased physical activity leads to increased motor competence, which in turn has a positive impact on weight status<sup>50</sup>. Motor competence is also positively associated with aerobic fitness, strength, endurance and body weight management in all under 18s<sup>48,51</sup>. There is also a positive association between family support and physical activity in children, Barnett *et al.*, (2016) has suggested that interventions to increase physical activity which involve family members are more likely to be successful, with the focus on finding activities that children enjoy, which create opportunities to be active, being the most important factor<sup>2,45,46</sup>.

A common misconception is that participation in extensive high intensity sport at this age alters growth rates, however, this has been shown not to be the case. It has also been suggested that children ready to play organised sport are ready for appropriate strength and conditioning training, with gymnastics or body weight management activities suggested to build foundational levels of strength<sup>52</sup>. However, overall time playing organised sport does not directly equate to physical activity time, suggesting that organised sport such as football only meets a portion of recommended activity. A study of 9-year olds playing 50 minutes of football showed that only 25% of the time was spent at moderate to vigorous activity, with children that were overweight or obese spending even less time at that activity level<sup>53</sup>.

One of the key benefits of physical activity in children is the positive effect on bone mineral density which is important for healthy aging. Bone growth and integrity are determined during growth and maturation in the prepubertal and early adolescent stages of growth. Failure to achieve sufficiently high bone mass during this period leads to increased risk of osteopenia and fragility fractures in older age due to age related bone demineralisation<sup>54,55</sup>. Research comparing prepubescent gymnasts (7 - 8 years old), who were regular participants in weight bearing and high impact training (8-10hrs per week, regularly for 3-4 years) showed that girls had a significantly greater (8-10%) bone mass than a matched untrained control group. This suggests similar activities which involve weight bearing and impact in childhood may confer benefits to skeletal health in later life<sup>55</sup>. An eight month intervention delivering 3 sessions a week of 10 -30 minutes incorporating games modified to include jumping, hopping and skipping (classed as vigorous

physical activity), with a minimum of 10 tuck jumps per session, was found to significantly increase the bone mineral density of the children taking part <sup>54</sup>. Children who report greater levels of participation in sport (boys: soccer, martial arts) and active play (girls: ballet, dance) have also been shown to have greater BMD at 7 years old <sup>40</sup>. In 6-9 year olds 40 minutes of PE a day (200 minutes per week) of moderate physical activity, 5 days a week, which included running, jumping, throwing and ball games over 3 years increased all round strength when compared to those only completing 60 minutes of PE over the week. It must be considered that increased physical activity has been proposed to contribute directly to an increase in fracture risk due to higher inherent exposure to injury (e.g., falls and collisions). It can however be considered to provide a protective effect on the risk of fracture due to a mechanical stimulus of bone formation, which potentially improves overall bone strength <sup>40</sup>.

Increased levels of physical activity are able to be linked with increased measures of fitness in boys but not girls suggesting increased physical activity alone is not enough to increase fitness <sup>56</sup>. Three 20 minute sessions per week which raised the heart rate to greater than 60% of heart rate reserve which include activities such as running, static cycling and mini trampoline bouncing have been shown to increase cardiovascular fitness after 6 weeks in children <sup>39</sup>. Children (boys and girls) aged 9-10 who cycled to school (a journey of 15min or less) were shown to be significantly fitter than those who took passive transport (car or bus) or walking. Although cycling and walking both contributed to physical activity, cycling showed a greater likelihood for vigorous activity <sup>57</sup>. Previous research <sup>41</sup> has also shown that primary school pupils trended towards decreased cardio vascular fitness and had significantly increased body mass index following the school summer holidays <sup>42,44</sup>. This suggests that ongoing activity interventions are important to provide children with the opportunity to engage with at least 15 to 20 minutes of vigorous activity on a minimum of three days per week, but ideally 5 days per week, especially in the school holidays and for those who do not take active forms of transport to school.

## Summary



The majority of children are not meeting their minimum recommended amount of physical activity. This may be due to parents overestimating the amount of physical activity particularly within organised sports, where 25% of total time is estimated to be moderate to vigorous. However, organised sport for children still plays an important role in helping them meet the physical activity guideline recommendations and for their wellbeing. Organised sporting activities have the potential to encourage children to engage in physical activity at times when activity might otherwise decline, such as at weekends and school holidays. Combined with the encouragement of active transport to school, particularly cycling, organised physical activity which includes 3 vigorous bouts of 10-30 minutes of jumping or similar weight bearing activity, with smaller bouts of moderate physical activity across the week, to achieve a daily average of 60 minutes over 8 weeks is supported by the literature presented here to have numerous health benefits for children. Importantly the research suggests that there is no upper limit to the amount of physical activity a child can participate in, as long as a gradual increase in activity levels is observed. Fun activities which include family support and have a mixture of skills (throwing, running, catching, jumping, balancing, gymnastics and bodyweight activities) should be targeted as these are likely to create positive, sustainable habits promoting the lifelong benefits of physical activity.

# 11 -16 years

With regards to general physical activity in adolescents much of the focus of the literature has been on physical education classes. In particular in recent years as a means to combat sedentary lifestyle factors, especially in girls, who are known to be less active than boys . In 11-12 year old girls it has been shown that approximately 30% of PE is at MVPA level. Up to a quarter of scheduled class time was found to be used up in activities such as changing and registration <sup>58</sup>. Subsequent research has shown that for both boys and girls (11-12 years old) only 30 - 40% of class time was spent in MVPA, equating to approximately 10-15min of the PE class <sup>59</sup>. When considering activity levels, time spent being physically active has been shown to be more important than the specific type of activity in young adolescents with regards to overall measures of health benefits <sup>60</sup>. Yet in older adolescents (17 years old) it has been shown that badminton players had a higher bone mineral density despite self-reported participation time being lower than for ice hockey players, for two matched groups, who participated in regular training for 5 years <sup>61</sup>. It is suggested that this is likely due to the nature of the short intensity loading (weight bearing) caused by the nature of badminton such as jumping, lunging and changes of direction.

It is unsurprising given the relatively short amount of time spent in PE that there is limited evidence for school and after school activity affecting overall activity levels in adolescents <sup>62</sup>. The most active adolescents (boys and girls) were found to take part in more outdoor activity than the least active, and for boys in particular it was found that organised sports contributed the most to activity levels. This suggests encouraging adolescents to be outside may be of value to increasing activity levels and interventions particularly aimed at girls would be beneficial. It has been highlighted that the most effective strategies to increase physical activity in adolescents should focus on the use of technology to deliver and monitor the activity levels, that non-curricular programmes and activities play an important role in increasing physical activity and programmes that respond to the needs and interests of girls should be prioritised <sup>63</sup>.

The benefits of continuing participation in physical activity for adolescents are similar to those of infants and children, with noted importance placed on weight bearing activities in order to increase bone mineral density. Adolescent trained runners (15-18 years) have been shown to have greater bone mineral density when compared to trained swimmers and cyclists, despite training for significantly fewer hours (8 vs. 15 hours respectively), demonstrating the importance of weight bearing activity<sup>64</sup>. An important factor affecting BMD is the dose of vigorous physical activity needed to induce a positive effect, particularly in adolescent girls. Stager et al. (2006) highlight that there is a lack of information regarding effects of specific activities and dose responses, however it is evident that weight bearing activity is important for life long skeletal health. Adolescents who participated in more sporting activities were shown to have a greater proportion of lean soft tissue mass which was linked to a greater bone mineral density, with little difference reported between sexes<sup>66</sup>. This suggests that interventions aimed at increasing sports participation and therefore moderate to vigorous physical activity can expect to see positive results in bone mineral density in both males and females. This may be particularly beneficial in adolescent girls where it has been shown that those participating in 3 hours per week of PE plus two additional sessions of 1.5 hours of volleyball, basketball or handball, had a BMD 5 to 9% higher than matched participants who took part in PE classes alone<sup>67</sup>. Encouraging participation of this kind is also important to encourage the life long benefits of improved BMD. Evidence shows that BMD can still be positively affected by weight bearing physical activity post puberty in sites exposed to osteogenic stimulation (activities which involve impacts)<sup>68</sup>.

Despite the limited time spent in PE, it has previously been shown that 15 minutes a day of interval based exercise that aimed to increase heart rate above 140 bpm (in this study classed as moderate to vigorous physical activity) during the school classes was enough to significantly improve young adolescents (11–13 years old) fitness, with girls showing twice the level of improvement than boys<sup>69</sup>. Vigorous physical activity in obese adolescents (15 years old) has also been shown to be more effective than moderate physical activity at improving cardio vascular fitness when controlling for total calorie expenditure per session over an 8 month training period<sup>70</sup>. This suggests that in young adolescents, particularly those who are

inactive, a minimum of 15 minutes a day of activity will confer some health benefits.

Alongside this, vigorous physical activity has also been shown to have a significant positive effect on wellbeing scores in adolescents participating in activities up to approximately 35 minutes per day. After this point vigorous physical activity was shown to have a negative effect on wellbeing which was more pronounced in females<sup>71</sup>. High intensity interval training, consisting of 8-10 minutes of activity 3 times per week of both aerobic and resistance training activities, has been shown to have both short and longer term impact on adolescents mental health<sup>72</sup>. These findings are similar to other studies which have found two exercise sessions per week of 30-60min of vigorous physical activity lead to improved reports of wellbeing in both adolescent boys and girls<sup>73,74</sup>.

Increased muscular strength has been found to be beneficial in adolescents for a variety of reasons. For instance, Grontved et al. (2015) found that increased abdomen and back strength at 15 years old was related to lower blood pressure, reduced BMI and fat levels, and reduced cardiovascular risk factor scores when retested in their 20's. As previously covered, increased participation in physical activity has been found to also increase risk of bone fractures<sup>76</sup>. However, ensuring that the type physical activity also improved strength, can mitigate this fracture risk<sup>77</sup>. Fritz et al. (2016) found that their 5 year school-based exercise intervention which included running, jumping and climbing increased levels of physical activity without affecting fracture risk. Foo et al. (2007) found that increased grip strength in adolescent girls was positively associated with forearm bone mineral content and bone area. While the evidence is limited, increased strength does appear to have both short- and long-term benefits for adolescents which can be improved through physical activity.

Although increases in strength have been shown to be beneficial, the types of exercise that are recommended to achieve this with 12 to 16 year olds is less clear. In a cross-sectional study, Moliner-Urdiales et al. (2010) found that of the five strength tests that they used, only standing broad jump was associated with increased MVPA. However, higher levels of VPA was positively related to all

strength tests. This suggests that, while the UK Government Guidelines recommend 60 minutes per day of MVPA, this intensity of physical activity may not be sufficient to elicit the required increases in strength. It has been suggested that regular bouts of MVPA (5 times per week) and less regular bouts of VPA (3 time per week) had health benefits in an overweight population in the lower end of this age bracket. This maybe generalisable to the general population, which is becoming invariably overweight <sup>81</sup>. Previous studies that have found strength increases and/or reductions in fracture risk with physical activity have included exercises such as jumping and climbing <sup>78</sup>; however, the general recommendation of including a diverse range of activities is potentially the most beneficial.

## Summary

It has been highlighted that for both male and female adolescents school PE classes provide the minimum amount of physical activity recommended to confer a health related benefit. Weight bearing activities such as running, jumping, climbing and team sports such as volleyball and handball played in addition to PE have shown a significant increase in health benefits. Encouraging these activities in teenagers as well as more time spent outside have been shown to increase the amount of moderate to vigorous physical activity adolescents take part in. It is clear that there is a need to address physical activity levels in adolescents, particularly females. Increasing physical activity in this age group should also seek to use technology in order to encourage engagement. On top of the government guidelines of an average of 60 minutes per day it appears that there is emerging evidence that at least 3 sessions of upto 30 minutes of vigorous activity should be aimed for, with 15 min of vigorous activity 3 times being considered as a minimum.

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