Association of Recess Provision with Elementary School-Aged Children's Physical Activity, Adiposity, and Cardiorespiratory and Muscular Fitness

Supplementary materials: https://osf.io/aq739

For correspondence: kimberly.clevenger@nih.gov

Kimberly A. Clevenger,[1] Melitta A. McNarry,[2] Kelly A. Mackintosh,[2] David Berrigan[1]

[1]National Cancer Institute, Rockville, MD, [2]Swansea University, Swansea, Wales

Please cite as: Clevenger KA, McNarry MA, Mackintosh KA, & Berrigan D. (2021). Association of Recess Provision with Elementary School-Aged Children's Physical Activity, Adiposity, and Cardiorespiratory and Muscular Fitness. *SportRχiv*.

ABSTRACT

Purpose: To identify associations between amount of school recess provision and children's physical activity (PA), weight status, adiposity, cardiorespiratory endurance, muscular strength, and muscular endurance. Method: Data from 6–11-year-old participants (n=499) in the 2012 National Youth Fitness Survey were analyzed. Parents/guardians reported children's PA levels and recess provision, categorized as no/minimal (9.0%), low (26.1%), medium (46.0%), or high (18.9%). Children wore a wrist-worn accelerometer for seven days and completed anthropometric measurements. Fitness was assessed using grip strength, and treadmill, pull-up, and plank tests. Cross-sectional linear and logistic regression compared outcomes across levels of recess provision adjusting for the survey's complex sampling design. Results: Children with high provision of recess were 2.31 times more likely to meet PA guidelines than those with no/minimal recess. Accelerometer-measured PA (overall, weekdays, and weekends) was higher in children with high compared to low recess provision. There were no associations with weight status, adiposity, or fitness. Conclusion: Provision of 30 mins of recess, 4-5 days•week-1 was associated with a two-fold-greater likelihood of achieving the PA levels recommended for health and wellbeing in youth. Recess provision should be protected within the school day due to its important role in the PA levels of youth.

INTRODUCTION

The United States (US) Physical Activity Guidelines for Americans (44) recommend that children participate in 60 mins•day-1 of moderate-to-vigorous physical activity (PA), as well as muscle- and bone-strengthening activities. Only 25.9% of children aged 6-13 years met the daily aerobic PA goals in 2016-2017 based on parent/guardian reports (15). There are numerous benefits associated with PA, including, but not limited to, reduced adiposity and risk for overweight/obesity, and improved cardiorespiratory and muscular fitness (43). Moreover, PA and associated benefits can track into adulthood (43, 53). Low PA levels in children is therefore a significant public health problem with potential long-term implications for population health.

School is an important opportunity in which to promote PA, not least because most children regularly attend and spend approximately half of their waking weekday time in this setting (based on a 7-hour school day). There are discrete periods which can be used to promote PA during the predominantly sedentary school day, namely Physical Education (PE) lessons, active classroom breaks, and recess. The purpose of PE is to develop knowledge and motor skills through sequential, planned instruction (16), while active classroom breaks seek to provide a few minutes of PA and simultaneously break prolonged sedentary periods, without leaving the classroom (21). In contrast, recess is the only opportunity for children to engage in unstructured free-play during the school day, offering children a respite from the supervision of adults and the structured nature of the classroom (20, 40). During recess, children may socialize, play, be physically active, and use their motor skills (41, 45).

Recess makes an important contribution to children’s daily PA levels (22, 36, 46, 49), with studies reporting that children spend approximately 40% of recess time in moderate-to-vigorous PA (19). Positive recess experiences have been shown to translate to additional PA due to increased PA enjoyment (37) and/or the development of foundational movement skills (31). Furthermore, PA during recess may contribute to improved cardiorespiratory fitness (18, 54), whilst specific activities, such as climbing playground equipment or using swings, may improve muscle strength and endurance (25, 28, 30). Nonetheless, the influence of recess provision on muscular and cardiorespiratory fitness remains to be fully elucidated, with scant literature available on how the amount of recess provided is associated with these outcomes.

Despite the known and potential benefits of recess, recess provision has declined over the last century (5, 6, 29, 40), a phenomenon largely attributed to increased focus on core academic subjects (38). Indeed, in the five years following the No Child Left Behind Act in 2001, schools that reduced recess provision did so by an average of 50 mins•week-1 (38). It is recommended that schools provide at least 20 minutes of daily recess (15, 50), but the amount of recess required to confer benefits, and indeed whether there is a dose-response relationship, is unknown. There is considerable variability in the amount of recess provided (13), which could be attributed to recess provision decisions being made at the school level or informed by district and state policy. Understanding the optimal duration and frequency of recess would inform school practices and policy. The aim of this study was to characterize the association of recess provision with PA, adiposity, weight status, cardiorespiratory endurance, and muscular strength and endurance.

METHOD

The National Youth Fitness Survey (NYFS) was designed as a supplement to the 2012 National Health and Nutrition Examination Survey (NHANES) to better capture the PA and physical fitness of non-institutionalized US children and adolescents aged 3-15 years. In 2012, participants were randomly sampled based on age and sex from dwelling units within segments (city blocks or equivalent) nested within the NHANES primary sampling units. The protocol was approved by the National Center for Health Statistics ethics review board in compliance with the Department of Health and Human Services policy for the protection of research participants.

Following informed parental/guardian consent and participant assent, a parent/guardian completed an interview at home and children completed assessments in a mobile examination center. The method has been fully described in Borrud et al. (7). In the present study, children aged 6-11 years were eligible for inclusion (Figure 1). Exclusion criteria included being classified as underweight according to Body Mass Index percentile (BMI; < 5th percentile), activity limited a lot, moderately, or a fair amount by wheezing, a physical limitation or health condition that affects ability to walk, run, or play, or receiving special education or early intervention services (i.e., services provided by the state or school system for children with special needs or disabilities). Moreover, given the specific focus on school recess, those who had only attended kindergarten or had never attended school, according to parent/guardian response to a question about the child's highest grade completed, were excluded.

Exposure

In the present study, the main exposure was recess provision, which was calculated from recess duration and frequency, as reported by the parent/guardians of the 6-11-year-old children during the interview. Parents/guardians who responded 'yes' to the question "Does (child's name) have recess during school days?" were asked to provide the frequency of recess as 'one day a week,' 'two days a week,' 'three days a week,' 'four days a week,' or 'every day'. Duration was reported in response to the question 'On average, how long is the recess period?' as 'less than 10 minutes', '10-15 minutes', '16-30 minutes', or 'more than 30 minutes'.

We classified overall recess provision as no/minimal, low, medium, or high based on a combination of the duration and frequency variables (Table 1). Specifically, the majority of children (~90%) fell in to four clear categories- no recess (4.7 ± 1.3%), or 10-15 minutes (20.1 ± 4.6%), 16-30 minutes (44.6 ± 4.3%), and more than 30 minutes (17.9 ± 2.8%), of recess five days•week-1. Estimates for other specific combinations of recess duration and frequency had insufficient reliability (>30% relative standard error) to be individually reported. Thus, while actual recess provision in minutes cannot be computed due to the NYFS categorical response options, the remaining combinations of duration and frequency (~10% of children) were sorted into the four aforementioned recess provision categories based on the approximate amount of recess provision to which they would equate. For example, >30 minutes of recess four days•week-1 would be greater than or equal to 120 minutes of recess weekly and was classified within the high recess provision category.

Outcome

Outcomes included PA, weight status, adiposity, cardiorespiratory endurance, muscular strength, and muscular endurance. PA was measured by parent/guardian report and accelerometry. Specifically, during the interview, parents reported a number from zero to seven days in response to the question "During the past week, on how many days did this child exercise, play a sport, or participate in physical activity for at least 60 minutes?" Responses were recategorized as meeting the US PA guidelines, and therefore engaging in at least 60 minutes of moderate-to-vigorous PA, seven days a week, or not. Children wore an ActiGraph GT3X+ on their non-dominant wrist for seven days following their visit to the mobile examination center. Daily Monitor-Independent Movement Summary (MIMS) units (32) for each participant were used to derive average MIMS overall, and for week and weekend days separately which were then compared to age- and sex-specific percentiles (4). The first and last wear day were removed (4) and only days with at least 10 hours of waking wear-time were included in the analyses (39).

Stature and body mass were measured using a SECA stadiometer and scale to the nearest 0.1 cm and 0.1 kg, respectively. BMI percentile was used to classify children as healthy weight (BMI ≥5th and <85th percentile) or overweight/obese (BMI ≥ 85th percentile). Adiposity was assessed as the sum of the calf, triceps, and subscapular skinfold thickness (mm; 8), which were each measured to the nearest 0.1 mm using the Holtain skinfold caliper.

Cardiorespiratory endurance was assessed as test duration (in seconds) using an age-appropriate treadmill walking and running test (11, 26). Muscular strength was assessed by relative grip strength and a pull-up test (33). Specifically, relative grip strength was measured using a dynamometer and calculated as maximum grip strength from each hand combined, divided by body mass. The pull-up test, measured by the number of pull-ups correctly completed, was conducted with participants lying on their back (12). Muscular endurance was assessed by a plank test, whereby the participant holds themselves in a prone, raised position on their forearms and toes with their back straight and is timed, in seconds, for how long they can hold the correct position (33). Relative grip strength and the timed plank results were compared to age- and sex-specific percentiles (33). However, the researchers who developed the percentiles for the pull-up test indicated that using specific percentiles was not advised due to the high proportion of children who complete no, or one, pull-ups (33), so the number of pull-ups completed was used as the outcome. Similarly, cardiorespiratory endurance was not compared to percentiles due to the limited number of age- and sex-specific percentiles available (26).

Statistical Analysis

Linear regression was used to compare continuous outcomes (overall, weekend, and weekday MIMS percentiles, grip strength percentiles, plank percentiles, cardiorespiratory endurance, pull-ups, and skinfold thickness) across recess provision categories. Logistic regression was used to estimate odds ratios for binary outcomes (meeting PA guidelines, overweight/obese), with no/minimal recess provision as the reference group. To account for their recognized effects on our outcomes (10, 14, 47, 55), the models were adjusted for race/ethnicity, grade (dichotomized as below vs. equal to or above 6th grade as this is when recess provision declines; 14), income to poverty ratio (accounts for family size and geographic residence), six-month measurement period when the exam was conducted, school sport participation, age and sex (when not an age- and sex-specific percentile) and weight status (except for adiposity, weight status, or grip strength outcomes).

All analyses accounted for the complex sampling design and incorporated the NYFS examination survey weights. Taylor series linearization was used to estimate variance. Analyses were conducted in RStudio (Vienna Austria; version 1.3.1056) using the 'survey' and 'emmeans' packages (versions 4.0 and 1.5.5, respectively). Unadjusted means that accounted for the survey design, but not covariates, were estimated using the 'svyby' command, while means adjusted for the survey design and covariates were derived using 'svypredmeans.' Means stratified by sex were calculated but formal statistical testing was not conducted by sex due to the small sample size. Significance was indicated when pairwise comparisons had a p-value of <0.05.

RESULTS

Participants (n=499) were 9.0 ± 0.1 years of age and had completed 1st to 6th grade (Table 2). In the US, children in 1st grade are approximately 6 years of age while children in 6th grade are approximately 12 years of age (although age was limited in the present study to 6-11 years of age). As shown in Table 1, almost half of the children had medium levels of recess provision (46.0 ± 4.3%), while fewer had no/minimal recess (9.0 ± 2.0%), low (26.1 ± 4.3%), or high (18.9 ± 3.0%) recess provision.

Unadjusted means and standard errors for all outcomes accounting for the survey design are reported in Table 3; corresponding bar charts are presented in Supplementary Figure 1. Outcomes in their original units (instead of percentiles) are shown in Supplementary Table 1. Marginal means adjusted for covariates and the survey design are reported in Supplementary Table 2, with means stratified by sex presented in Supplementary Tables 3 (boys) and 4 (girls).

The odds of a parent reporting that their child met PA guidelines were 2.31 (95% confidence interval: 1.04, 5.13) times higher in those with high levels of recess provision compared to those with no/minimal recess provision. When comparing the group means (Table 3), parents reported approximately one additional day of 60 minutes of PA in children with high levels of recess provision compared to no/minimal recess (5.9 vs. 4.3 days, respectively). Children with high recess provision had significantly higher overall, weekday, and weekend MIMS percentiles, in comparison to children with low recess provision (+16, 14, and 15 percentile points, respectively). Children with no/minimal recess provision had higher weekend MIMS compared to children with low recess provision (+13 percentile points).

Odds of being overweight were not significantly different across levels of recess provision when using no/minimal recess provision as the referent group. There were no significant pairwise differences between levels of recess provision in skinfold thickness or any of the fitness outcomes (cardiorespiratory endurance, relative grip strength percentile, plank percentile, or pull- ups).

TABLES AND FIGURES

Table 1. Percent of children (± standard error) with each level of recess provision, which was categorized using parent-reported frequency and duration of recess

Recess Provision	Frequency and Duration	Percent ± SE
No/Minimal	No recess	9.0 ± 2.0
	1 day•week^{-1}, any duration	
	2 days•week^{-1}, ≤ 30 min/recess	
	3 days•week^{-1}, ≤ 15 mins•recess^{-1}	
	4-5 days•week^{-1}< 10 mins•recess^{-1}	
Low	2 days•week^{-1}, > 30 mins•recess^{-1}	26.1 ± 4.3
	3 days•week^{-1}, 16-30 mins•recess^{-1}	
	4 days•week^{-1}, 10-30 mins•recess^{-1}	
	5 days•week^{-1}, 10-15 mins•recess^{-1}	
Medium	3 days•week^{-1}, > 30 mins•recess^{-1}	46.0 ± 4.3
	5 days•week^{-1}, 16-30 mins•recess^{-1}	
High	4-5 days•week^{-1}, >30 mins•recess^{-1}	18.9 ± 3.0

Table 2. Participant characteristics and recess provision. Data are shown as mean ± standard error and are adjusted for the complex sampling design of the National Youth Fitness Survey.

Characteristic	Mean ± SE
Age (years)	9.0 ± 0.1
Sex (%)	
Boys	45.9 ± 1.6
Girls	54.1 ± 1.6
Race (%)	
Mexican-American	14.1 ± 4.1
Other Hispanic	10.2 ± 3.8
Non-Hispanic White	50.3 ± 5.9
Non-Hispanic Black	14.2 ± 3.8
Other race or multi-racial	11.2 ± 2.9
Grade (%)	
1st	23.6 ± 2.3
2nd	19.3 ± 1.5
3rd	22.3 ± 1.9
4th	22.6 ± 2.3
5th	10.7 ± 1.3
6th	1.5 ± 0.5
Income to poverty ratio	2.5 ± 0.2
Sport participation (%)	47.2 ± 3.7
Measurement period (%)	
November 1 through April 30	62.7 ± 11.6
May 1 through October 31	37.3 ± 11.6

Table 3. Unadjusted physical activity, weight status, adiposity, and fitness by level of recess provision. Significant differences are listed below the mean ± standard error, adjusted for the complex sampling design of the National Youth Fitness Survey.

	Recess Provision			
	No or Minimal	Low	Medium	High
Meeting physical activity guidelines (%)	37.4 ± 5.8 High	58.5 ± 3.2 -	53.7 ± 4.7 -	62.7 ± 5.6 No/Minimal
Parent-reported physical activity (days)	4.3 ± 0.3 Low, High	5.8 ± 0.1 No/Minimal	5.7 ± 0.2 -	5.9 ± 0.2 No/Minimal
Overall MIMS (percentile)	53.3 ± 5.3 -	45.7 ± 3.5 High	53.3 ± 1.6 -	61.6 ± 2.7 Low
Weekday MIMS (percentile)	54.0 ± 5.4 -	49.8 ± 3.6 High	56.3 ± 1.6 -	64.0 ± 2.6 Low
Weekend MIMS (percentile)	50.1 ± 5.4 Low	37.0 ± 3.9 No/Minimal, High	45.3 ± 1.8 -	51.9 ± 3.1 Low
Overweight or obese (%)	47.7 ± 7.4 -	33.6 ± 5.9 -	32.9 ± 2.3 -	43.0 ± 7.1 -
Skinfold thickness (mm)	42.5 ± 3.8 -	41.1 ± 2.0 -	39.7 ± 1.5 -	38.1 ± 2.9 -
Relative grip strength (percentile)	48.4 ± 5.5 -	50.4 ± 2.8 -	50.3 ± 2.1 -	49.7 ± 2.8 -
Plank (percentile)	48.7 ± 6.3 -	60.4 ± 2.8 -	57.3 ± 3.1 -	53.6 ± 4.1 -

All authors have read and approved this version of the manuscript. This article was last modified on Month XX, YEAR.

Authors X *@xtwitter* and Y *@ytwitter* can be reached on Twitter.

Pull-up (number)	5.2 ± 1.5 -	5.4 ± 0.6 -	4.7 ± 0.4 -	4.2 ± 0.3 -
Cardiorespiratory endurance (s)	641.5 ± 24.0 -	654.1 ± 17.0 -	645.4 ± 11.6 -	660.7 ± 19.1 -

MIMS: monitor-independent movement summary. Differences indicate pairwise differences significant at a level of $p<0.05$

DISCUSSION

This study explored the association of amount of recess provision with children's PA, weight status, adiposity, cardiorespiratory endurance, muscular strength, and muscular endurance, to inform school practices and policy. The findings indicate that high levels of recess (>30 minutes, 5 days•week-1), beyond currently recommended levels (15, 50), are positively associated with PA, but not weight status, adiposity, muscular fitness, or cardiorespiratory endurance. These results demonstrate the important role of recess as a PA opportunity for youth, highlighting the need for recess provision to be protected within the school day.

Irrespective of assessment type (parent/guardian report or device-based), children with high levels of recess provision engaged in the most PA. Specifically, children with the highest levels of recess provision participated in approximately one more day a week of PA according to parent/guardian report and had significantly higher levels of both week and weekend day PA, according to device-based data. This study therefore supports the consensus that recess is fundamental for children's overall PA levels (6, 20, 22, 36, 45, 46, 49) and builds on previous research by examining the association of recess with week and weekend day PA. While PA on weekend days is consistently lower than week days (9), our findings are congruent with prior research that indicated the most active children are better able to maintain PA on weekend days (23). The ability of a school-based intervention to influence weekend behavior is supported by Sigmund et al. (51) who reported that an intervention providing 6-9 year-old Czech children with additional PA opportunities during school (including recess) improved weekend PA (51). These findings support that sufficient recess, beyond current recommendations (15, 50), may be a strategy for increasing the number of children who meet PA guidelines.

Despite the general finding that high levels of recess provision facilitate PA, the device-based data followed more of a U- or J-shaped curve, in which children with no/minimal recess provision had similar levels of overall, week and weekend day PA as those with high levels of recess provision (Supplementary Figure 1). Parent/guardian report did not reveal the same U/J-shaped curve, but rather, a typical dose-response in which more recess resulted in higher PA levels. There are at least two potential explanations for this pattern. One explanation is that children with no/minimal recess provision compensate for low levels of PA opportunity with additional, unplanned activity, or an increase in intensity within specific activities (48). An example of this type of activity could occur if a child runs instead of walks up the stairs. The MIMS unit (32) captures total PA volume, so this type of behavior would be captured by the accelerometer but may not be considered by parents when reporting their child's PA levels. There may also be reporting bias wherein parents assume children are physically active during recess. Of note, parents responded to the overall PA question prior to questions regarding recess. No information was available about the type of school children attended, so it is possible that children with no/minimal recess are in a unique situation (e.g., home schooling). These children may not have traditional 'recess' but have other opportunities for PA during the day.

Children's weight status and adiposity were characterized by BMI percentile and skinfold thickness, respectively, but there were no differences by level of recess provision. In contrast to our null cross-sectional findings, Fernandes and Sturm (24) reported in their longitudinal study that recess provision of at least 100 mins•week-1 was associated with a 0.74 point reduction in a child's BMI percentile from 1st to 5th grade (~7-11 years of age). In addition to differences in study design, our null findings for weight status may be due to classification of children as healthy weight versus overweight/obese; however, sensitivity analyses using age- and sex-specific BMI percentiles also showed no association with recess provision (data not shown). Follow-up studies employing a longitudinal design are needed to clarify these discrepancies. This study found no relationship between recess provision and cardiorespiratory endurance, plank percentile, relative grip strength percentile, or pull-ups completed. Changes in fitness are dependent on baseline fitness levels (1, 2) so future research should seek to identify whether recess differentially benefits children with the lowest fitness levels (we do not have the sample size for this type of sub-group analysis). While not statistically significant, we note that children with lower recess provision tended to have higher fitness levels. There may be other PA opportunities for which we could not control. For example, while we controlled for school sport participation, PE provision may confound the relationship between recess provision and fitness as previous research indicates an inverse relationship between provision of recess and PE (52). Information related to PE was not provided by study participants but the mixed findings regarding the effects of PE on fitness (42) make it unclear if/how this would impact our results.

The intensity, duration, and type of activity during recess are likely important moderators of the relationship between provision of recess and children's fitness that were not captured in the survey analyzed in this study. Prior research on PE (42) and recess (54) indicates that PA intensity during the class or recess period is associated with the accompanying fitness benefits. It is important to consider activity type, as some children may engage in muscle-strengthening exercises, while others may do activities that are not aligned with fitness, such as socializing. Activity type and intensity is also affected by markings on the schoolyard and/or the type/amount of equipment, which have been associated with children's fitness (25, 28, 30). In addition to information about children's behavior during recess, the quality of recess provided should be considered. A recent review of PE interventions indicates that improving the quality, instead of the quantity, of PE may be sufficient to improve fitness (27). Capturing the context and quality of recess may provide a better understanding of the association of fitness with recess provision.

Although there are strengths of this study, including the use of a nationally representative sample, a major limitation is the cross-sectional design. Further, while these are the most up-to-date US surveillance data, it is unknown if or how relationships between recess provision and these outcomes may have changed, particularly in response to the COVID-19 pandemic. Parents may be more familiar with the amount of scheduled or planned recess, which may not align with the actual amount provided. The use of pre-defined categories for recess duration and frequency makes it difficult to disentangle exactly how much recess is beneficial. Moreover, parents did not report frequency of recess per day which precludes us from estimating actual volume of recess provided or exploring how the pattern of recess provision is associated with outcomes. Despite this limitation, we note that children with high recess provision definitively exceed the recommendation of 20 min of daily recess so positive effects in this group can be interpreted as a positive effect of providing children with more recess than is currently being recommended. Regardless, future surveillance efforts may benefit from assessing recess provision more precisely.

As boys are more active than girls during recess and participate in different activities (19, 47), we reported means stratified by sex but did not examine statistical associations for these subsets due to the small sample size. There do not appear to be obvious differences by sex in the association of recess with outcomes (Supplementary Tables 3 and 4) but future research should examine whether the benefits of recess are consistent by sex or other characteristics, such as socioeconomic status, congruent with prior PE research (34). It is noteworthy that biological maturation, which impacts PA levels, adiposity, and fitness (3), was not controlled for in the present study. While our sample included younger children (6-11 years), some early-maturing girls may have been nearing their period of peak growth in which the largest changes in these outcomes occur (35). Lastly, a third of participants had measurements conducted between May and October. If a child was not in school at the time of the assessment, parents responded to recess questions according to when the child was last in school. As the outcomes considered here are typically poorer during school breaks (10), this would weaken their relationship with recess; parents would report typical recess provision even though children were not actually receiving recess. Nonetheless, whilst the statistical power was reduced, removal of these participants did not influence the overall findings (data not shown). While we only had statistical power to detect medium-to-large effects in the present study, the results may inform future surveillance efforts.

Overall, high levels of recess provision (>30 mins•day-1) were positively associated with PA but less than 20% of children receive this amount of recess. The majority of children in the present study (46%), and the majority of schools according to national surveillance data (59%; 13), provided ‘medium’ levels of recess. Indeed ‘medium’ levels of recess provision are in line with recommendations (17, 50) and a Healthy People 2020 objective which sought to increase the number of school districts requiring 20 minutes of scheduled recess per day (15). Prior to modification of these recommendations, the costs and benefits of additional recess (including on educational outcomes) should be considered and larger scale cross-sectional or longitudinal studies using more specific measures of recess provision are needed to inform policy makers.

Contributions

Contributed to conception and design: KC
Contributed to acquisition of data: KC
Contributed to analysis and interpretation of data: KC, MM, KM, DB
Drafted and/or revised the article: KC, MM, KM, DB
Approved the submitted version for publication: KC, MM, KM, DB

Funding information

None

Data and Supplementary Material Accessibility

This paper uses data from the National Youth Fitness Survey (https://www.cdc.gov/nchs/nnyfs/index.htm)
Supplemental material is available at https://osf.io/aq739

REFERENCES

1. Armstrong N, Barker AR. Endurance training and elite young athletes. Med Sport Sci. 2011;56:59-83. DOI: 10.1159/000320633
2. Barker A, Lloyd RS, Buchheit M, Williams C, Oliver J. The BASES expert statement on trainability during childhood and adolescence. Sport Exerc Sci. 2014;41:22-3.
3. Baxter-Jones AD, Sherar LB. Growth and maturation. Paediatric exercise physiology. Elsevier; 2007:299-324.
4. Belcher BR, Wolff-Hughes DL, Dooley EE, Staudenmayer J, Berrigan D, Eberhardt MS, et al. US Population-referenced percentiles for wrist-worn accelerometer-derived activity. Med Sci Sport Exerc. 2021. Online first. DOI: 10.1249/MSS.0000000000002726
5. Blatchford P. The state of play in schools. Child Psychology and Psychiatry Review. 1998;3(2):58-67.
6. Bohn-Gettler CM, Pellegrini AD. Recess in primary school: The disjuncture between educational policy and scientific research. Justice, Conflict and Wellbeing: Springer; 2014:313-36. DOI: 10.1007/978-1-4939-0623-9_12
7. Borrud LG, Chiappa M, Burt V, Gahche JJ, Zipf G, Dohrmann SM, et al. National Youth Fitness Survey Plan, operations and analysis, 2012. Vital Health Stat. 2014;163:-24.
8. Brambilla P, Bedogni G, Heo M, Pietrobelli A. Waist circumference-to-height ratio predicts adiposity better than body mass index in children and adolescents. Int J Obes. 2013;37(7):943-6. DOI: 10.1038/ijo.2013.32

9. Brazendale K, Beets MW, Armstrong B, Weaver RG, Hunt ET, Pate RR, et al. Children's moderate-to-vigorous physical activity on weekdays versus weekend days: a multi-country analysis. Int J Behav Nutr Phys Act. 2021;18(1):1-13. DOI: 10.1186/s12966-021-01095-x
10. Brusseau TA, Burns RD. Children's weight gain and cardiovascular fitness loss over the summer. Int J Environ Res Public Health. 2018;15(12):2770. DOI: 10.3390/ijerph15122770
11. Centers for Disease Control and Prevention. National youth fitness survey (NYFS) treadmill examination manual. Hyattsville, MD: National Center for Health Statistics. 2013. https://www.cdc.gov/nchs/data/nnyfs/treadmill.pdf
12. Centers for Disease Control and Prevention. National Youth Fitness Survey (NYFS) modified pull-up exercise procedures manual. 2013 www.cdc.gov/nchs/data/nnyfs/Modified_Pullup.pdf.
13. Centers for Disease Control and Prevention. School Health Policies and Practices Study 2014 Overview. 2014. https://www.cdc.gov/healthyyouth/data/shpps/pdf/2014factsheets/2014_overview_fact_sheet.pdf
14. Centers for Disease Control and Prevention. Results from the school health policies and practices study 2014. US Department of Health and Human Services. 2015. p. 60-74.
15. Centers for Disease Control and Prevention. Health People 2020. https://health.gov/healthypeople/objectives-and-data/browse-objectives/physical-activity/increase-proportion-children-who-do-enough-aerobic-physical-activity-pa-09/data.
16. Centers for Disease Control and Prevention. Physical Education. 2020. https://www.cdc.gov/healthyschools/physicalactivity/physical-education.htm
17. Centers for Disease Control and Prevention and SHAPE America. Strategies for Recess in Schools. CDC Atlanta, GA; 2017.
18. Chen W, Hammond-Bennett A, Hypnar A, Mason S. Health-related physical fitness and physical activity in elementary school students. BMC Public Health. 2018;18(1):1-12. DOI: 10.1186/s12889-018-5107-4
19. Clevenger KA, Wierenga MJ, Howe CA, Pfeiffer KA. A systematic review of child and adolescent physical activity by schoolyard location. Kinesiol Rev. 2020;9(2):147-58. DOI: 10.1123/kr.2019-0009
20. Council on School Health. The crucial role of recess in school. 2013;131(1):183-188.
21. Daly-Smith AJ, Zwolinsky S, McKenna J, Tomporowski PD, Defeyter MA, Manley A. Systematic review of acute physically active learning and classroom movement breaks on children's physical activity, cognition, academic performance and classroom behaviour: understanding critical design features. BMJ Open Sport Exerc Med. 2018;4(1): e000341. DOI: 10.1136/bmjsem-2018-000341
22. Erwin H, Abel M, Beighle A, Noland MP, Worley B, Riggs R. The contribution of recess to children's school-day physical activity. J Phys Act Health. 2012;9(3):442-8. DOI: 10.1123/jpah.9.3.442

23. Fairclough SJ, Boddy LM, Mackintosh KA, Valencia-Peris A, Ramirez-Rico E. Weekday and weekend sedentary time and physical activity in differentially active children. J Sci Med Sport. 2015;18(4):444-9. DOI: 10.1016/j.jsams.2014.06.005
24. Fernandes MM, Sturm R. The role of school physical activity programs in child body mass trajectory. J Phys Act Health. 2011;8(2):174-81. DOI: 10.1123/jpah.8.2.174
25. Gabbard C. Playground Apparatus Experience and Muscular Endurance among Children 4-6. Texas A and M University. 1979.
26. Gahche JJ, Kit BK, Fulton JE, Carroll DD, Rowland T. Normative Values for Cardiorespiratory Fitness Testing Among US Children Aged 6-11 years. Pediatr Exerc Sci. 2017;29(2):177-85. DOI: 10.1123/pes.2016-0167
27. García-Hermoso A, Alonso-Martínez AM, Ramírez-Vélez R, Pérez-Sousa MÁ, Ramírez-Campillo R, Izquierdo M. Association of physical education with improvement of health-related physical fitness outcomes and fundamental motor skills among youths: A systematic review and meta-analysis. JAMA Pediatr. 2020;174(6):e200223-e. DOI: 10.1001/jamapediatrics.2020.0223
28. Grunseit AC, O'Hara BJ, Drayton B, Learnihan V, Hardy LL, Clark E, et al. Ecological study of playground space and physical activity among primary school children. BMJ Open. 2020;10(6):e034586. DOI: 10.1136/bmjopen-2019-034586
29. Heck WH. A Study of School Recesses: University of Virginia; 1917;3(1):1-22.
30. Heneghan C. The effect of fixed playground equipment on primary school children's fitness levels. Irish Teachers' Journal. 2016:99.
31. Hulteen RM, Morgan PJ, Barnett LM, Stodden DF, Lubans DR. Development of foundational movement skills: A conceptual model for physical activity across the lifespan. Sports Med. 2018;48(7):1533-40. DOI: 10.1007/s40279-018-0892-6
32. John D, Tang Q, Albinali F, Intille S. An Open-Source Monitor-Independent Movement Summary for Accelerometer Data Processing. Journal for the Measurement of Physical Behaviour. 2019;2(4):268-81. DOI: 10.1123/jmpb.2018-0068
33. Laurson KR, Saint-Maurice PF, Welk GJ, Eisenmann JC. Reference curves for field tests of musculoskeletal fitness in US children and adolescents: The 2012 NHANES National Youth Fitness Survey. J Strength Cond Res. 2017;31(8):2075-82. DOI: 10.1519/JSC.0000000000001678
34. Lin W, Leider J, Shang C, Hennessy E, Perna FM, Chriqui JF. The association between state physical education laws and student physical activity. Am J Prev Med 2020;58(3):436-45. DOI: 10.1016/j.amepre.2019.09.018
35. Malina RM, Bouchard C, Bar-Or O. Growth, maturation, and physical activity: Human Kinetics; 2004.
36. Massey WV, Stellino MB, Fraser M. Individual and environmental correlates of school-based recess engagement. Prev Med Rep. 2018;11:247-53. DOI: 10.1016/j.pmedr.2018.07.005
37. Massey WV, Stellino MB, Mullen SP, Claassen J, Wilkison M. Development of the great recess framework–observational tool to measure contextual and behavioral components of

elementary school recess. BMC Public Health. 2018;18(1):1-11. DOI: 10.1186/s12889-018-5295-y
38. McMurrer J. Instructional time in elementary schools: A closer look at changes for specific subjects: Center on Education Policy; 2008.
39. Migueles JH, Cadenas-Sanchez C, Ekelund U, Nyström CD, Mora-Gonzalez J, Löf M, et al. Accelerometer data collection and processing criteria to assess physical activity and other outcomes: a systematic review and practical considerations. Sports Med. 2017;47(9):1821-45. DOI: 10.1007/s40279-017-0716-0
40. Pellegrini AD. The recess debate: A disjuncture between educational policy and scientific research. Am J Play. 2008;1(2):181-91.
41. Pellegrini AD, Smith PK. School recess: Implications for education and development. Rev Educ Res. 1993;63(1):51-67. DOI: 10.3102/00346543063001051
42. Peralta M, Henriques-Neto D, Gouveia ÉR, Sardinha LB, Marques A. Promoting health-related cardiorespiratory fitness in physical education: A systematic review. Plos One. 2020;15(8):e0237019. DOI: 10.1371/journal.pone.0237019
43. Physical Activity Guidelines Advisory Committee. 2018 Physical activity guidelines advisory committee scientific report. US Department of Health and Human Services; 2018.
44. Piercy KL, Troiano RP, Ballard RM, Carlson SA, Fulton JE, Galuska DA, et al. The physical activity guidelines for Americans. JAMA. 2018;320(19):2020-8. DOI: 10.1001/jama.2018.14854
45. Ramstetter CL, Murray R, Garner AS. The crucial role of recess in schools. J Sch Health. 2010;80(11):517-26. DOI: 10.1111/j.1746-1561.2010.00537.x
46. Reilly JJ, Johnston G, McIntosh S, Martin A. Contribution of school recess to daily physical activity: systematic review and evidence appraisal. Health Behav Policy Rev. 2016;3(6):581-9. DOI: 10.14485/HBPR.3.6.7
47. Ridgers ND, Salmon J, Parrish A-M, Stanley RM, Okely AD. Physical activity during school recess: a systematic review. Am J Prev Med. 2012;43(3):320-8. DOI: 10.1016/j.amepre.2012.05.019
48. Ridgers ND, Timperio A, Cerin E, Salmon J. Within-and between-day associations between children’s sitting and physical activity time. BMC Public Health. 2015;15(1):1-7. DOI: 10.1186/s12889-015-2291-3
49. Rooney L. Contribution of physical education and recess towards the overall physical activity of 8-11 year old children. J Sport Health Res. 2018;10(2):303-16.
50. SHAPE America. Guide for recess policy. Reston, VA. 2016. Retrieved from https://www.shapeamerica.org/advocacy/upload/Guide-for-Recess-Policy.pdf
51. Sigmund E, El Ansari W, Sigmundová D. Does school-based physical activity decrease overweight and obesity in children aged 6–9 years? A two-year non-randomized longitudinal intervention study in the Czech Republic. BMC Public Health. 2012;12(1):1-13. DOI: 10.1186/1471-2458-12-570

52. Slater SJ, Nicholson L, Chriqui J, Turner L, Chaloupka F. The impact of state laws and district policies on physical education and recess practices in a nationally representative sample of US public elementary schools. Arch Pediatr Adolesc Med, 2012;166(4):311-6. DOI: 10.1001/archpediatrics.2011.1133
53. Telama R. Tracking of physical activity from childhood to adulthood: a review. Obes Facts. 2009;2(3):187-95. DOI: 10.1159/000222244
54. Torres-Luque G, López-Fernández I, Carnero EA. Sedentariness and physical activity during school recess are associated with VO2Peak. Int J Environ Res Public Health. 2020;17(13):4733. DOI: 10.3390/ijerph17134733
55. Wolfe AM, Lee JA, Laurson KR. Socioeconomic status and physical fitness in youth: Findings from the NHANES National Youth Fitness Survey. J Sports Sci. 2020;38(5):534-41. DOI: 10.1080/02640414.2020.1713688