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# The association of physical growth and behavior change with Preschooler's physical fitness: From 10- years of monitoring data☆

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ABSTRACT

*Background:* This study examined the trends of physical fitness among children aged 3–6 years old and identified the factors associated with the change of children's physical fitness.
*Methods:* Datum were from two cross-sectional surveys in 2005 and 2015. Children aged 3–6 years old in China Macao were recruited from 6 kindergartens. 6 kindergartens were selected from North, South and Central districts, and two kindergartens in each district using random cluster sampling in 2005. The same 6 kindergartens were selected in 2015. Physical fitness testing and a survey on children behavior were conducted for all children.
*Results:* Standing long jump, shuttle run, sit and reach, and continuous jump of children in Macao improved significantly in some age groups from 2005 to 2015 ($P < 0.05$). Results of general linear model showed that: (1) The effect of height and weight on physical fitness was less than test year effect (standing long jump: partial $\eta 2$ of height = 4.5%, partial $\eta 2$ of time = 8.5%); (2) after adjusted age, gender and parental education level, participating in sports clubs was associated with standing long jump($\beta = 5.827$,$p = 0.048$) and shuttle run ($\beta = -0.759$, $p = 0.042$) in 2015. Less sedentary entertainment time and participating in sports club were two Interactive protecting factors of improving throwing ability ($\beta = 1.862$, $p = 0.045$).
*Conclusions:* The changes in height and weight were not the whole reason for the change of physical fitness among Macao preschoolers. The behaviors, including participating in sports clubs and the less time of watching TV were associated with children's running, jumping and throwing.



## Introduction

The period from 3 to 6 years of age is especially critical for children's growth and development. The development of young children's physical fitness not only promotes their participation in outdoor activities, but also has great significance for the development of adult sports habits and health.[1]

Since 2000, China has regularly monitored the physical fitness of children aged between 3 and 6 years, including strength, running speed, balance, flexibility and coordination ability. Monitoring data over the past decades show that among Chinese children, some of these physical fitness indicators, the strength of lower and running speed, have improved, while balance and flexibility have worsened.[2–4] Factors influencing children's physical fitness include innate physique and learned behavior. Much research has demonstrated that the effects of height and weight on children's physical fitness differ.[5,6] In recent years, with great improvement in nutritional conditions, the height and weight of Chinese children have increased rapidly.[4] The relationship between changes in body growth and physical fitness thus warrants further study.

The decline in physical activity (PA) is an important behavioral factor influencing children's physical fitness (PF). Compared with adults, the relationship between PA and PF is more complex in children, and especially in very young children.[7,8] In addition, studies have shown that early skill acquisition also has a positive effect on PF.[9,10] A four-year follow-up study showed that children

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who regularly participate in sports clubs have high levels of physical fitness.[11] In China, parents attach great importance to their children's early education, and enroll them in interest classes to learn various skills from an early age. In the past 10 years, the percentage of children attending interest classes in Macao has increased from 40% to 70%, and the percentage attending sport clubs has doubled.[12] Nowadays, children play outside less frequently and for a shorter time than their parents, and their patterns of activity are also changing. Research has shown that children's physical activity has shifted from unstructured, non-directive outdoor activities toward structured, directed indoor activities.[7] However, it is unclear how these changes affect children's physical fitness, and reports on effects in the early stages of childhood are particularly sparse.

During the past 10 years, children's physique and physical activity patterns have undergone significant changes in Macao China. The purpose of this study was to examine the trends and factors influencing children's physical fitness and to provide a valuable reference for promoting the physical fitness and health of preschool children.

## Methods

### *Participants*

We recruited children aged 3–6 years from six kindergartens in North, South and Central Districts in Macao in 2005, and cluster sampling was used to select each kindergarten.[4] Two kindergartens were randomly selected from each district. The same kindergartens were selected in 2015. All children in six kindergartens took part in the test after eliminating motor and intellectual disorders. In total, 1050 and 1068 children were included in our study in 2005 and 2015. This study was approved by the Ethics Committee of China Institute of Sport Science. Written informed consent was provided by children's parents.

### *Measures*

Height, weight, physical fitness testing and a survey on behavior and household background were conducted for all children. Physical fitness indicators were the standing long jump, overhand throw, 2 × 10 m shuttle run, sit and reach, balance beam walk and two-legged continuous jump.[4] The items on the questionnaire included childbirth conditions, children's physical activity, parents' educational level and exercise behaviors, etc.[12]

### *Questionnaire*

To carry out physical fitness monitoring in 2005, the Macao Sports Bureau had developed a questionnaire on children's physical fitness according to the local children's social conditions and activity characteristics. The main indicators of the questionnaire included children's birth conditions, illness, outdoor activities, interest classes, time spent watching TV, sleep, breakfast habits, parents' educational background, occupation. There were 19 questions in total. The answer forms were single-choice and multiple-choice. The development process of the questionnaire could be found in “Macao citizens' physical fitness monitoring report 2015”.[12] The questionnaires were filled out by parents of young children. The valid number of questionnaires collected in 2005 and 2015 was 1006 and 998. The data of the questionnaires were entered by double entry method.

### *Data analyses*

A general analysis of children's physical fitness indicators was conducted. The difference between test years was analyzed using the independent sample T test, and the factors influencing physical fitness were analyzed using the generalized linear model (GLM). In analyzing the effects of body shape and year on physical fitness, the physical fitness indicators were considered as dependent factors with test year, height and weight as independent factors, and age and gender as covariates. We analyzed the effects of learned behaviors on children's physical fitness, using children's early feeding practices, incidents of illness, time spent on outdoor activity, time spent watching TV or playing on the computer, participation in physical education clubs (PE), and test year as independent variables, while considering gender, age, height and weight as covariates. Independent variables with p-values $\leqq 0.05$ were included in the final model (see Table 1).

## Results

Tables 2 and 3 shows the change of height and weight and fitness of children from 2005 to 2015. The height and weight significantly improved from 2005 to 2015 in some age groups ($P < 0.05$).Standing long jump significantly improved at 4 years old in boys and girls. Sit and reach significantly improved at 3 and 6 years old in boys. 2 × 10 m shuttle run and continuous jump significantly improved at 4 and 5 years old in boys and girls($P < 0.05$).

Table 4 showed that children's height was significantly associated with physical fitness, weight was significantly associated with overhand throw and two-legged continuous jump. According to the GLM results (Table 5), for children of the same gender and age, height was a positive factor improving standing long jump, Overhand throw, run and continuous jump, with partial $\eta^2$ increasing from 1.9% to 4.5%; on the other hand, height was a negative factor hindering the performance of sit and reach. Weight was a positive factor for upper body strength (overhand throw: $\eta^2 = 9.8\%$), while it was a negative factor for performance on the two-legged continuous jump ($\eta^2 = 1.5\%$). The effect of test year on standing long jump, sit and reach, run and balance walk was greater than that of physique based on partial $\eta$.[2] For standing long jump, we have partial $\eta^2$ of test year = 8.5% while partial $\eta^2$ of height = 4.5% and partial $\eta^2$ of weight = 1.5%.

From Table 6, the time of outdoor play and watching TV decreased and the proportion of participating the PE club increased from 2005 to 2015. We used the GLM model analyze the children's behaviors and parental condition on the children's physical fitness. The test result of between-group effect showed that children's early feeding practices, incidents of illness, time spent on outdoor activity had no effect on children's fitness. From Table 7, After adjusted age, gender and parent's education level, participation in PE clubs was associated with improvement on the standing long jump and shuttle run. and there was a strong interaction between participation in PE clubs and test year. The effect of participating in PE club in 2015 on jumping and running performance was significantly better than that of participating in 2005. As a matter of fact,

**Table 1**
Sample size in each year.

| Year | 3~ | | 4~ | | 5~ | | 6~ | |
|---|---|---|---|---|---|---|---|---|
| | Boys | Girls | Boys | Girls | Boys | Girls | Boys | Girls |
| 2005 | 159 | 116 | 140 | 132 | 180 | 133 | 99 | 91 |
| 2015 | 205 | 127 | 180 | 131 | 221 | 140 | 41 | 23 |

**Table 2**
Height and weight of children aged 3–6 years old, in 2005 and 2015.

| | | Height | | Weight | |
|---|---|---|---|---|---|
| | | 2005 | 2015 | 2005 | 2015 |
| boys | 3~ | 99.3 ± 3.9 | 99.4 ± 4.0 | 15.1 ± 1.8 | 15.3 ± 1.9 |
| | 4~ | 105.5 ± 4.4 | 106.4 ± 4.6[a] | 17.1 ± 2.4 | 17.4 ± 2.5 |
| | 5~ | 112.0 ± 4.9 | 112.3 ± 4.7 | 19.5 ± 3.2 | 19.8 ± 3.2 |
| | 6 year | 117.6 ± 5.3 | 117.8 ± 5.1 | 21.4 ± 4.0 | 22.5 ± 3.5[a] |
| girls | 3~ | 97.1 ± 3.9 | 98.8 ± 4.5[a] | 14.7 ± 1.9 | 14.9 ± 1.9 |
| | 4~ | 104.6 ± 4.6 | 105.0 ± 4.7 | 17.0 ± 2.5 | 17.6 ± 2.4[a] |
| | 5~ | 111.7 ± 4.7 | 111.9 ± 4.5 | 19.0 ± 2.7 | 19.2 ± 2.5 |
| | 6 year | 116.8 ± 4.3 | 116.9 ± 3.9 | 20.5 ± 4.0 | 21.6 ± 2.8[a] |

[a] Comparison between 2015 and 2005 , $P < 0.05$.

**Table 3**
Changes in physical fitness of children aged 3–6 years in Macao between 2005 and 2015.

| Indicators | Year | 3~ | | 4~ | | 5~ | | 6~ | |
|---|---|---|---|---|---|---|---|---|---|
| | | Boys | Girls | Boys | Girls | Boys | Girls | Boys | Girls |
| standing long jump (cm) | 2005 | 55.6 ± 10.2 | 51.3 ± 11.3 | 69.0 ± 11.8 | 64.8 ± 11.1 | 92.6 ± 19.7 | 86.0 ± 15.2 | 99.7 ± 18.5 | 92.4 ± 17.4 |
| | 2015 | 54.3 ± 10.0 | 49.9 ± 12.2 | 77.6 ± 11.9 | 75.4 ± 12.6 | 94.1 ± 20.2 | 87.6 ± 17.8 | 104.3 ± 20.2 | 95.0 ± 17.2 |
| | P | .397 | .493 | .000 | .000 | .368 | .346 | .136 | .484 |
| overhand throw (m) | 2005 | 2.9 ± 0.9 | 2.4 ± 0.8 | 4.0 ± 1.5 | 3.4 ± 1.2 | 5.7 ± 1.8 | 4.4 ± 1.3 | 6.0 ± 2.1 | 5.3 ± 1.7 |
| | 2015 | 2.7 ± 0.8 | 2.2 ± 0.7 | 4.0 ± 1.6 | 3.3 ± 1.1 | 5.4 ± 1.4 | 4.2 ± 1.1 | 5.8 ± 2.0 | 5.1 ± 1.6 |
| | P | .091 | .172 | .936 | .589 | .064 | .246 | .455 | .641 |
| sit and reach (cm) | 2005 | 8.0 ± 3.1 | 9.4 ± 4.1 | 7.5 ± 2.9 | 8.5 ± 3.6 | 7.1 ± 2.7 | 9.5 ± 4.2 | 4.5 ± 2.8 | 6.4 ± 2.6 |
| | 2015 | 10.2 ± 4.0 | 10.4 ± 3.9 | 7.8 ± 2.5 | 8.9 ± 3.7 | 7.6 ± 2.1 | 10.0 ± 4.1 | 7.5 ± 2.2 | 9.0 ± 4.3 |
| | P | .000 | .026 | .490 | .558 | .240 | .385 | .001 | .031 |
| 2 × 10 m shuttle run (s) | 2005 | 9.9 ± 1.7 | 10.1 ± 1.8 | 8.3 ± 1.3 | 8.6 ± 1.5 | 7.3 ± 1.0 | 7.7 ± 1.2 | 6.6 ± 0.9 | 6.9 ± 1.0 |
| | 2015 | 9.8 ± 1.7 | 9.9 ± 1.8 | 7.8 ± 1.3 | 8.2 ± 1.2 | 6.9 ± 1.1 | 7.1 ± 1.0 | 6.5 ± 0.8 | 6.9 ± 0.8 |
| | P | .356 | .317 | .000 | .001 | .000 | .000 | .348 | .791 |
| walking balanced beam (s) | 2005 | 18.9 ± 10.2 | 17.9 ± 11.3 | 11.2 ± 7.8 | 12.2 ± 8.2 | 6.8 ± 3.1 | 9.4 ± 5.5 | 5.7 ± 3.1 | 5.9 ± 3.0 |
| | 2015 | 22.1 ± 12.2 | 22.5 ± 12.9 | 12.6 ± 8.1 | 12.8 ± 7.9 | 7.6 ± 4.9 | 6.4 ± 3.8 | 6.4 ± 3.9 | 7.4 ± 5.1 |
| | P | .020 | .016 | .100 | .613 | .175 | .000 | .211 | .053 |
| two-leg continuous jump (s) | 2005 | 13.4 ± 4.9 | 12.8 ± 3.8 | 10.0 ± 3.9 | 10.4 ± 3.2 | 7.6 ± 2.8 | 7.9 ± 2.6 | 6.7 ± 1.8 | 6.8 ± 1.7 |
| | 2015 | 13.7 ± 5.1 | 13.2 ± 5.9 | 9.1 ± 3.7 | 9.1 ± 3.6 | 6.9 ± 1.7 | 6.7 ± 1.1 | 6.0 ± 1.3 | 6.3 ± 1.7 |
| | P | .568 | .528 | .020 | .005 | .002 | .000 | .031 | .216 |

**Table 4**
Correlation of physical fitness with height, weight, and BMI.

| | | Standing long jump | Overhand throw | Sit and reach | Shuttle run | Walking balance beam | Two-legged continuous jump |
|---|---|---|---|---|---|---|---|
| Height | correlation | .220 | .120 | -.082 | -.196 | -.107 | -.123 |
| | *P* (two-side) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Weight | correlation | -.044 | **.093** | .039 | .030 | .044 | **.058** |
| | *P* (two-side) | .056 | <0.01 | .086 | .198 | .056 | .011 |
| BMI | correlation | −0.182 | −0.234 | −0.002 | 0.203 | 0.075 | 0.081 |
| | *P* (two-side) | <0.01 | <0.01 | **.945** | <0.01 | **.001** | <0.01 |

**Table 5**
Effects of physique and test year on physical fitness.

| | Standing long jump | | | Overhand throw | | | Sit and reach | | | Shuttle run | | | Balance beam walk | | | Continuous jump | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | β | Sig. | $\eta^2$ | β | Sig. | $\eta^2$ | β | Sig. | $\eta^2$ | β | Sig. | $\eta^2$ | β | Sig. | $\eta^2$ | β | Sig. | $\eta^2$ |
| Height | 0.950 | <0.01 | 0.045 | 0.050 | 0.01 | 0.019 | −0.186 | 0.03 | 0.019 | −0.057 | <0.01 | 0.029 | −0.021 | 0.680 | 0.001 | −0.154 | <0.01 | 0.021 |
| Weight | −0.244 | 0.468 | 0.015 | 0.066 | 0.015 | 0.098 | 0.043 | 0.683 | 0.001 | 0.001 | 0.96 | 0.001 | 0.046 | 0.475 | 0.001 | 0.179 | 0.03 | 0.015 |
| Test year[a] | −8.683 | <0.01 | 0.085 | 0.106 | 0.253 | 0.002 | −2.56 | <0.01 | 0.049 | 0.431 | <0.01 | 0.038 | −0.944 | 0.034 | 0.018 | 0.940 | 0.01 | 0.019 |

[a] 2015 is the reference group.

the interaction coefficient (β) of participation in PE clubs*test year 2015 was 5.827 for standing long jump, and 2.254 for shuttle run, with p-value < 0.05. The results in Table 7 also suggested that participation in PE clubs interacted with time spent watching TV. Watching TV for less than 1 h and participation in PE clubs were significantly associated with improved performance in overhand throw, when compared with watching TV for more than 1 h or not participating in PE.

## Discussion

Our study explored the changes in Macao children's physical fitness over the past 10 years, and found that lower-limb strength, running speed, coordination and flexibility have improved significantly in some age groups. Our further analysis showed that the increases in height and weight were not the whole reason for the changes in physical fitness: learned behaviors, including the

**Table 6**
Behavior change in 2005 and 2015.

| | | 2005 | 2015 |
|---|---|---|---|
| n | | 1006 | 998 |
| outdoor play | ≤30min | 25.0% (22.4%–27.7%) | 27.1% (24.3%–29.8%) |
| | 30miñ1 h | 42.0% (39.0%–45.1%) | 49.3% (46.2%–52.4%) |
| | 1–2 h | 24.5% (21.8%–27.1%) | 18.8% (16.4%–21.3%) |
| | 2 h | 10.5% (8.6%–12.4%) | 4.8% (3.5%–6.1%) |
| watching TV | ≤1 h | 40.0% (36.9%–43.0%) | 60.9% (57.9%–63.9%) |
| | 1–2 h | 34.8% (31.8%–37.7%) | 25.6% (22.8%–28.3%) |
| | ≥2 h | 24.2% (21.5%–26.8%) | 13.5% (11.4%–15.6%) |
| PE club | | 14.9% (12.7%–17.1%) | 24.5% (21.9%–27.2%) |

**Table 7**
Factors influencing children's physical fitness from GLM analysis.

| Factor | Standing Long Jump | | | 10-meter Shuttle Run | | | Overhand Throw | | |
|---|---|---|---|---|---|---|---|---|---|
| | β | Sig. | 95% CI | β | Sig. | 95% CI | β | Sig. | 95% CI |
| Gender(girl) | −4.791 | <0.01 | −6.115 to 3.471 | 0.204 | <0.01 | 0.140 to 0.342 | −0.625 | <0.01 | −0.770 to-0.481 |
| Age | 17.192 | <0.01 | 16.528 to 17.861 | −1.224 | <0.01 | −1.275 to1.137 | 1112 | <0.01 | 1058 to1.181 |
| Parent's education level | | | | | | | | | |
| mother | 0.900 | 0.093 | −0.150 to1.950 | −0.012 | 0.761 | −0.093 to 0.068 | −0.016 | 0.715 | −0.099 to 0.068 |
| father | 0.238 | 0.613 | −0.683 to1.159 | −0.028 | 0.441 | −0.098 to 0.043 | −0.026 | 0.502 | −0.101to 0.049 |
| Test year (2015) | 6.161 | 0.001 | 0.583 to12.906 | −0.770 | 0.001 | −0.298 to 0.252 | −0.272 | 0.054 | −1.895 to 0.113 |
| PE club | 4.820 | 0.096 | −9.006 to18.566 | −0.424 | 0.054 | −0.923to1.077 | 0.186 | 0.348 | 0.012 to 0.756 |
| Outdoor play | | | | | | | | | |
| 1–2 h | 0.607 | 0.913 | −4.702 to 5.529 | -.340 | .908 | −0.612 to 0.544 | 0.620 | 0.048 | 0.004 to1.236 |
| 30miñ1 h | 0.406 | 0.826 | −5.792 to 4.536 | -.150 | .955 | −0.034 to 0.503 | 0.395 | 0.160 | −0.157 to 0.947 |
| Less than 30 min is the reference group | | | | | | | | | |
| PE club*Test year | | | | | | | | | |
| [PE = 1] * [2015] | **5.827** | **0.048** | **0.798 to12.431** | **−0.759** | **0.042** | **−0.832 to 2.350** | 0.277 | 0.737 | −0.134 to1.879 |
| [PE = 2] * [2015] | 0.471 | 0.661 | −1637 to 2.579 | −0.109 | 0.165 | −0.264 to 0.045 | −0.337 | 0.000 | −0.494 to 0.180 |
| 2005 is the reference group | | | | | | | | | |
| PE = 1TV ≤ 1 h | 4.633 | .685 | −17.791to27.057 | −0.324 | 0.129 | −0.033 to 0.385 | **1.862** | **0.045** | **0.041to 3.682** |
| PE = 1*TV 1–2 h | −1.953 | .864 | −24.242to20.335 | −1.230 | 0.079 | −2.929 to 1.469 | 1.701 | 0.065 | −0.103 to 3.515 |
| PE = 1*TV ≥ 2 h | -.800 | .946 | −24.014to22.415 | 0.089 | 0.921 | −1.680 to1.859 | 0.422 | 0.660 | −1.461 to 2.307 |
| Not participated in PE club is the reference group | | | | | | | | | |

Participated in PE club = 1 , Not participated in PE club = 2.

increased percentage of children participating in PE clubs and reduced time spent watching TV, were also associated with the improvement in children's jumping, running and throwing ability. These motor skills are the fundamental abilities in early childhood and are the basis for learning complex sport skill in the future. The change in children's physical fitness is a global health concern. Studies show that children's physical fitness has been declining globally over the past few decades.[13,14] However, few studies have described changes over time in the physical fitness of children aged 3–6 years. The present study found that from 2005 to 2015, among 3-to-6-year-old children in Macao, China, four of the six indicators used to gauge physical fitness improved, one worsened and one was relatively stable. The improved indicators of physical fitness were mainly lower-limb strength, speed and coordination. A comparison with Chinese research indicates that the changes over time in the physical fitness of children in Macao are similar to those observed nationwide.[4,15,16]

The physical fitness of children was influenced by both innate factors and acquired lifestyles. This study has explored factors affecting physical fitness related to children's physical development and learned behaviors. Among these, researchers have always considered height and weight to be the important factors. Some researchers have found that children with normal weight have much better physical fitness than those who are overweight, especially in terms of aerobic capacity, sensitivity and homeostasis, while obese children have better static balance.[17] A study from Li et al.[18] showed that the height and chest circumference of pre-school children was positively associated with performance on the standing long jump and overhand throw. The results of the present study show that for children of the same age and gender, taller children performed better on the standing long jump, overhand throw, $2 \times 10$ m shuttle run, two-legged continuous jump, and balance beam walk. Heavier children performed better on the overhand throw. However, weight was a negative factor for lower-limb jumping items, which means heavier children had worse performances on the standing long jump and two-legged continuous jump.

We further compared the effects of physique and test year on physical fitness. Our results indicated that the effects of height and weight on four Physical Fitness Indicators were smaller than that of test year. Therefore, the changes in height and weight were not the whole reason for the improvement in physical fitness.

Learned behaviors are important factors affecting children's health. In our study, the general linear model (GLM) was used to identify the factors influencing physical fitness from children's daily activities and parental sport habits and educational level, and

analyzed the interaction between these influence factors and the test year. We found that both sports club participation and screen time were significantly associated with children's physical fitness. Children who participated in sports clubs performed better on the standing long jump and 2 × 10 m shuttle run. Interestingly, these associations were only observed in 2015, which suggests a link with the fact that the proportion of children participating in sports clubs doubled to 24% in 2015, and a link with what they learned in the sports clubs. In fact, the lessons taught in sports clubs were likely directly associated with the improvement of physical fitness. Although we did not investigate the specific lessons children learned in sports clubs, we can gain some clues indirectly from children activities information published by Macao Sports Bureau Website. The activities such as gymnastics, roller skating and Taekwondo are the popular children's sports club courses for children. These activities are more helpful in improving lower-limb strength and speed. Some scholars have studied the effects of sports club participation on the physical fitness of children[19] and found that the learned sport item had low relation with the physique level, while high-intensity PA was highly related. The mechanism by which learning fundamental movement skills promotes children's physical fitness is still an open question. Researchers think that fundamental movement skills learning trains for a high level of neuromuscular coordination. It is also the mechanism for the development of speed, agility and strength.[19] Therefore, participation in sports clubs and PE classes involving these skills can promote children's physical fitness. In addition to the proportion of participants and the PE course, other possible reasons should be responsible for the interaction only in 2015. For example, there may be more significant factors affecting children's fitness, which covered the effect of PE club in 2005. Future study is required to identify the impact of early club participation on children's physical fitness and explore mechanisms of association.

The present study found that, among those who participated in sports clubs, children who spent less than 1 h a day watching TV performed better on the overhand throw, compared with those who watched more than 1 h of TV. Thus, participation in sports clubs alone may not be enough to improve children's strength, and excessive sedentary time should also be reduced. In some studies on children's screen time and physical fitness, researchers found that children who watched less than 2 h of TV were 4 times more likely to be qualified on the physical fitness test than the control group.[20] Webster found children's motor skills was inversely related to screen time, and more associated with more VPA but not MVPA.[21] One cross-sectional study used a predictive model for analysis. Replacing sedentary time with moderate-intensity physical activity was not associated with any fitness indicators.[22] It seems relatively independent that the influence of sedentary behavior and physical activity on children's physical fitness. In this study, we did not find that watching TV and outdoor activities had a significant impact on any physical indicators, but found that moderate screen time combined with participation in sports clubs had a positive effect on improving throwing ability. It is suggested that children's motor skills learning, besides sedentary behavior and physical activity, should also be included in the analysis insight of influencing factors in future studies.

In contradiction to our hypothesis, this study found no link between outdoor play time and physical fitness. The dose-effect relationship between physical activity and physical fitness is not as clear in children as it is in adults. The results reported in the related studies are not consistent,[23–25] which is probably due to the complexity of assessing children's physical activities. At present, the available data only confirm that the relationship between physical activities and aerobic endurance is related to the intensity of the activity. Cross-sectional and longitudinal studies suggest that increased participation in intense physical activities, rather than light/moderate physical activities, may be positively associated with children's aerobic endurance.[3] Although our study did not observe any direct association between the time children spend playing outdoors and their physical fitness, that does not mean that outdoor activities are not important. Playing outdoors is of great benefit for children's physical and mental health. In our previous study,[26] we assessed the physical activities of Beijing children with accelerometers, and found that only 40% of children meet the PA recommendation of at least 1 h/day of moderate-to-vigorous physical activity (MVPA). To meet the MVPA requirement, these children need outdoor activities after school. Although we do not have data on the physical activity level of children in Macao, we recommend that children in Macao should not only take an active part in sports clubs, but also make sure to spend enough time playing outdoors.

How children's daily PA and skills learning influence the development of children's physical fitness is a complex research issue which warrants extensive, profound investigation. The present study, which was conducted with two sets of survey data spanning 10 years, yielded significant results. However, the cross-sectional study design used here poses limitations for further analysis. If a fixed population can be followed up and studied longitudinally in the future, we will be able to provide better evidential support for the identification and assessment of factors influencing children's physical fitness.

## Conclusion

The physical fitness of children in Macao has changed significantly during the past 10 years. The changes in height and weight were not the whole reason for the change of physical fitness. The learned behaviors, including participating in PE clubs and less time of watching TV, were associated with children's running, jumping and throwing abilities. The influence of PE club participation on children's physical fitness needs further study.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jesf.2019.07.001.

## References


1. Ortega FB, Ruiz JR, Castillo MJ, Sjöström M. Physical fitness in childhood and adolescence: a powerful marker of health. *Int J Obes*. 2008;32:1–11.
2. Lie YH, Dong ZZ. *Statistical Analysis of Guangxi Children's Physique Changes Compare to the National Average Popular Science & Technology*. 2014:151–154.
3. Sigmundsson H, Haga M. Motor competence is associated with physical fitness in four- to six-year-old preschool children. *Eur Early Child Educ Res J*. 2016;24:477–488.
4. Tian LY. *Dynamic changes of physiques of Chinese 3 - 6 year - old preschoolers from 2000 to 2010*34. Shandong Sports Science & Technology; 2012:88–92.
5. M K, B T, M S, N F, N Z. Anthropometric influence on physical fitness among preschool children: gender-specific linear and curvilinear regression models. *Coll Antropol*. 2013;37:1245–1252.
6. Opstoel K, Pion J, Elferink-Gemser M, et al. Anthropometric characteristics, physical fitness and motor coordination of 9 to 11 Year old children participating in a wide range of sports. *PLoS One*. 2015;10, e0126282.
7. Gray C, Gibbons R, Larouche R, et al. What is the relationship between outdoor time and physical activity, sedentary behaviour, and physical fitness in children? A systematic review. *Int J Environ Res Public Health*. 2015;12:6455–6474.
8. Zaqout M, Vyncke K, Moreno LA, et al. Determinant factors of physical fitness in European children. *Int J Public Health*. 2016;61:573–582. International Journal of Public Health.
9. Hands B. Changes in motor skill and fitness measures among children with high and low motor competence: a five-year longitudinal study. *J Sci Med Sport*. 2008;11:155–162.
10. Lopes VP, Rodrigues LP, Maia JAR, Malina RM. Motor coordination as predictor of physical activity in childhood. *Scand J Med Sci Sport*. 2010;21:663–669.
11. Golle K, Granacher U, Hoffmann M, Wick D, Muehlbauer T. Effect of living area

and sports club participation on physical fitness in children: a 4 year longitudinal study. *BMC Public Health*. 2014;14:499.
12. Mei W, feng ZY, min Jc. *Macao Citizens' Physical Fitness Monitoring Report 2015*. Sports Bureau of the Macao Administrative Region; 2016.
13. Morales-Demori R, Jamil O, Serratto M. Trend of endurance level among healthy inner-city children and adolescents over three decades. *Pediatr Cardiol*. 2016;38:123–127.
14. Tomkinson GR, Olds TS. Secular changes in pediatric aerobic fitness test performance: the global picture. *Med Sport Sci*. 2007;50:46–66.
15. Tao L. The analysis on the variation trends of physical fitness of children in recent decade in ya'an city. *Sichuan Sports Sci*. 2013;15:46–48.
16. Ruo-feng Z, Dian-sheng F, Shui-ping X, Li-hua M. Children(3-6 years old) Physical fitness situation and trend in hainan province. *Nat Sci J Hainan Univ*. 2013;31:364–369.
17. Niederer I, Kriemler S, Zahner L, et al. BMI group-related differences in physical fitness and physical activity in preschool-age children: a cross-sectional analysis. *Res Q Exerc Sport*. 2012;83:12–19.
18. Yi-chen L, Panying. Canonical correlation analysis on body shape and quality indicators of preschool children in Beijing. *Chin J Child Health Care*. 2011;19:707–709.
19. Fransen J, Deprez D, Pion J, et al. Changes in physical fitness and sports participation among children with different levels of motor competence: a 2-year longitudinal study. *Pediatr Exerc Sci*. 2014;26:11–21.
20. Z S, A W, M S. Analysis on condition and influence factors of infant' fitness by multimonimal logistic regression. *Mod Prev Med*. 2009;36:4211–4214.
21. Webster EK, Martin CK, Staiano AE. Fundamental motor skills, screen-time, and physical activity in preschoolers. *Journal of Sport and Health Science*. 2019;8:114–121.
22. Leppänen MH, Nyström CD, Henriksson P, et al. Physical activity intensity, sedentary behavior, body composition and physical fitness in 4-year-old children: results from the ministop trial. *Int J Obes*. 2016;40:1126–1133.
23. Bürgi F, Meyer U, Granacher U, et al. Relationship of physical activity with motor skills, aerobic fitness and body fat in preschool children: a cross-sectional and longitudinal study (Ballabeina). *Int J Obes*. 2011;35:937–944.
24. Gutin B, Yin Z, Humphries MC, Barbeau P. Relations of moderate and vigorous physical activity to fitness and fatness in adolescents. *Am J Clin Nutr*. 2005;81:746–750.
25. Ruiz JR, Rizzo NS, Hurtig-Wennlöf A, Ortega FB, àrnberg JW, Sjöström M. Relations of total physical activity and intensity to fitness and fatness in children: the European youth heart study. *Am J Clin Nutr*. 2006;84:299–303.
26. Xing Z, Si-long Z, Dong-mei L, Jia-lin Z. Intensity level of different kinds of outdoor physical activities in kindergarten and the related influencing factors. *China Sport Sci*. 2016;36:34–41.