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

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ARTICLE INFO

Article history:
Received 20 February 2019
Received in revised form
2 July 2019
Accepted 10 July 2019
Available online 10 July 2019

Keywords:
Young children
Physical fitness
Physical growth
Outdoor activity
Sports clubs

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 η2 of height = 4.5%, partial η2 of time = 8.3%); (2) after adjusted age, gender and parental education level, participating in sports clubs was associated with standing long jump (β = 5.827, p = 0.048) and shuttle run (β = -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 (β = 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.

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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.5,10 A four-year follow-up study showed that children...
who regularly participate in sports clubs have high levels of physical fitness. 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 classes has doubled. 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. 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. 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. The items on the questionnaire included birth conditions, children’s physical activity, parents’ educational level and exercise behaviors, etc.

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’. 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 ≤ 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 η² 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: η² = 9.8%), while it was a negative factor for performance on the two-legged continuous jump (η² = 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 η². For standing long jump, we have η² of test year = 8.5% while partial η² of height = 4.5% and partial η² 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

| 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   |
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
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 physical fitness of children was in influence 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. A study from Li et al. showed that the height and chest circumference of preschool 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 × 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

Table 6
Behavior change in 2005 and 2015.

| Factor                     | 2005          | 2015          |
|----------------------------|---------------|---------------|
| n                          | 3017          | 3003          |
| outdoor play               | 1066          | 998           |
| ≤ 30 min                   | 25.0% (22.4%–27.7%) | 27.1% (24.3%–29.8%) |
| 30 min to 1 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%–44.0%) | 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                      | 2005          | 2015          |
|-----------------------------|---------------|---------------|
| Gender (girl)               | −4.791        | <0.01         |
| Age                         | 17.192        | <0.01         |
| Parent’s education level    |               |               |
| mother                      | 0.900         | 0.093         |
| father                      | 0.238         | 0.613         |
| Test year (2015)            | 6.161         | 0.001         |
| PE club                     | 4.820         | 0.096         |
| Outdoor play                |               |               |
| 1–2 h                       | 0.607         | 0.913         |
| 30 min to 1 h               | 0.406         | 0.826         |
| PE club*Test year           |               |               |
| [PE – 1] * [2015]          | 5.827         | 0.048         |
| [PE – 2] * [2015]          | 0.471         | 0.661         |
| 2005 is the reference group |               |               |
| PE – TV ≤ 1 h               | 4.633         | 0.685         |
| PE – TV 1–2 h               | −1.953        | 0.864         |
| PE – TV ≥ 2 h               | −0.800        | 0.946         |
| Not participated in PE club |               |               |

Participated in PE club = 1, Not participated in PE club = 2.
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 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 consistent movement-related skill-building trains for a high level of neuromuscular coordination. It is also the mechanism for the development of speed, agility and strength.

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. Webster found children's motor skills was inversely related to screen time, and more associated with more VPA but not MVPA. 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. 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, 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. 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, 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 evidence of 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.

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