SHORT COMMUNICATION

Tracking handgrip strength in kindergarteners and nursery school children

Akemi Abe, Jeremy P. Loenneke, Scott J Dankel, Takashi Abe

Handgrip strength (HGS) assesses a child's muscular strength and is also a biomarker of future health. To achieve high HGS by adulthood, observing changes in children's HGS during their development is helpful. However, few studies have yet tracked changes in HGS in young children.

Objectives: This study aimed to track the HGS of young children and clarify how children's HGS changes over time.

Design: Follow-up study

Methods: Ninety-one young children (48 boys and 43 girls) aged 3.5 to 4.5 years participated in an initial HGS measurement and repeated measurements 1 and 2 years later. Tracking of HGS was assessed using Spearman correlation coefficients (r) and Foulkes and Davies' tracking index (γ).

Results: The Spearman coefficient (r) of HGS for the first year, from 4 to 5 years of age, was low to moderate (range 0.38-0.59) in boys and girls. However, it was high (range 0.74-0.84) for the second year compared with the first year, from 5 to 6 years of age. The tracking index (γ) ranged from 0.55 to 0.56 for boys and 0.60 to 0.62 for girls (right, left, and average both hands).

Conclusion: HGS tracking outcomes for young children were low to moderate based on the two assessments used in this study. Our results indicate that environmental factors, including physical, mental, and cognitive development, may influence changes in HGS in children at this age. However, the target levels at each age required to achieve high HGS by adulthood are still being determined, and further follow-up studies are needed.

(*Journal of Trainology* 2025;14(1):6-9)

Keywords: ■ biomarker ■ follow-up study ■ grip strength ■ young children

INTRODUCTION

Available evidence supports that maintaining a higher handgrip strength (HGS) is desirable throughout life.[1] HGS increases dramatically during growth and development[2,3], but genetic and non-genetic factors influence this change[4,5] and likely contribute toward individual differences[2,3]. HGS is more than just an indicator for evaluating muscular strength in children and adolescents. Low HGS in adolescence may be associated with a higher risk of suicide in young adults[6] and prediabetes or type-2 diabetes rates in middle-aged adults[7]. Furthermore, low HGS in middle-aged and older adults may be associated with higher morbidity and premature mortality.[8,9] Given that improvements in HGS are limited in middle-aged adults[10,11], developmental periods may be important for achieving higher HGS[12].

In cross-sectional studies, HGS is measured each school year, and the results are evaluated. However, there is a difference of about one year between early and late-born children in each school year, and the impact of this age difference may only be considered in some cases. Meanwhile, tracking studies can help us understand how HGS changes with age by continuously monitoring the developmental process of individual HGS in children and adolescents. In particular, in young children, maturity and the ability to receive guidance improve as they grow, which may affect the measurement of HGS.[2] A study[13] tracked two physical fitness components (aerobic fitness and grip strength) measured annually over 5 years from late childhood (about 10 years old) through adolescence (about 14 years old). They reported that HGS over 5 years showed moderate to high relationships in boys and girls. Another study[14] measured children's physical fitness, including HGS, in schoolchildren (ages 8, 10, 12, and 14 at baseline) twice, with each measurement separated by two years. The authors reported good tracking of HGS over the 2-year period. The results from the above studies suggest that HGS is stable through late childhood and adolescence and that adolescents with low HGS tend to remain low. To our knowledge, however, studies have yet to track changes in HGS in young children. Therefore, this study aimed to track HGS of kindergarten and nursery school children and clarify how children's

Received December 1, 2024; accepted February 13, 2025

From the Division of Children's Health and Exercise Research, Institute of Trainology, Fukuoka, Japan (A.A., T.A.), Department of Health, Exercise Science, and Recreation Management, Kevser Ermin Applied Physiology Laboratory, The University of Mississippi, Oxford, MS, USA (J.P.L.), Department of Health and Exercise Science, Rowan University, Glassboro, NJ, USA (S.J.D.), and Graduate School of Health and Sports Science, Institute of Health and Sports Science & Medicine, Juntendo University, Chiba, Japan (T.A.)

Communicated by Naotoshi Mitsukawa, Ph.D.

Correspondence to: Akemi Abe, Division of Children's Health and Exercise Research, Institute of Trainology, Fukuoka 814-0001, Japan
Email: amyabe3379@gmail.com

HGS changes over time.

METHODS

Participants

One hundred twenty-four children (65 boys and 59 girls) from local kindergarten and nursery schools participated in this study. The inclusion criteria were children between 3.5 and 4.5 years of age at the start of the study and were free of injury for strength testing. Written informed consent was obtained from the parents of each child before the initial measurements. All data collection occurred at the facilities they attended in the morning between 9:00 and 11:00 am. All participants completed the first measurement and had their second and third measurements one year and two years after the first measurement. Twenty-two participants (13 after one year and nine after two years) were transferred to other facilities due to their parents' jobs. Eleven participants could not take the second and third measurements due to injury or illness. Therefore, the final sample included for analysis consisted of 91 children (48 boys and 43 girls) (Table 1). A few participants (one boy and two girls) used their left hands to eat and write. This study received approval from the University's Institutional Review Board (application no SG #2021-2-2).

HGS measurements

Maximal voluntary HGS was measured using a Smedley handgrip dynamometer (Grip-A, Takei Kiki Kogyo Co. Ltd., Niigata, Japan) in the standing position.[15] The distance of the dynamometer grip bars (grip span) was set each measurement year for the children's hand size (30% of hand length: the linear distance between the distal wrist crease and the tip of the middle finger). Children were allowed to perform two maximal trials with a one-minute break for the right and left hands (alternating right and left). The measurer instructed the children to exert all their strength. The research team gave verbal encouragement during handgrip strength measures. The highest value in each hand and the average value of both hands were used for data analysis.

Before the HGS measurements, standing height and body mass were measured using a calibrated digital height and weight scale (DST-210S, Muratec KDS Corp, Kyoto, Japan) to the closest 0.1 cm and 0.1 kg. Body mass index was calculated as the body mass divided by height square (in kilograms per square meter).

Statistical analysis

Participant physical characteristics variables were reported as mean ± standard deviations. Two methods were used to examine the tracking of HGS over time. First, because Spearman rank correlation coefficients have been used in tracking studies of physical fitness indicators[13,14], they were also calculated in this study to estimate the predictive power between first-year and second-year outcomes and between second-year and third-year outcomes. Second, the tracking index (γ) proposed by Foulkes and Davies was calculated as reported in a previous study.[16] This index varies between $0 < \gamma < 1$ and details the percentage of individual data points that do not intersect. No tracking is indicated to occur if $\gamma < 0.5$, perfect tracking corresponds to $\gamma = 1$, and values closer to 1 indicate a higher degree of tracking.[16]

In this study, the interpretation of correlation coefficients was defined as follows: 0.00~0.25 indicated no correlation, 0.26~0.49 indicated low correlation, 0.50~0.69 indicated moderate correlation, 0.70~0.89 indicated high correlation, and 0.90~1.00 indicated very high correlation.

RESULTS

Table 1 shows the Spearman correlation coefficients. The correlation coefficients of HGS for both boys and girls were higher between the second and third years of measurement than between the first and second years of measurement. Furthermore, the coefficients were similar for the right hand, left hand, and average of both hands.

The tracking index of the average HGS of the right and left hands was 0.555 (95% CI: 0.510, 0.600) for boys, 0.625 (95% CI: 0.576, 0.674) for girls, and 0.613 (95% CI: 0.586, 0.640) for the overall sample. Similarly, the tracking index for HGS of the right and left hands was 0.551 (95% CI: 0.504, 0.598)

Table 1. Three-year changes in anthropometric variables and handgrip strength in young children

	Boys (n=48)			Girls (n=43)			Overall (n=91)		
	First	Second	Third	First	Second	Third	First	Second	Third
Age (yr)	4.0 (0.3)	5.0 (0.3)	6.0 (0.3)	4.1 (0.3)	5.1 (0.3)	6.1 (0.3)	4.1 (0.3)	5.1 (0.3)	6.0 (0.3)
Height (cm)	100.3 (4.1)	106.9 (4.3)	113.6 (4.3)	99.5 (5.3)	106.4 (5.5)	112.8 (5.7)	99.9 (4.7)	106.6 (4.9)	113.3 (5.0)
Body mass (kg)	15.9 (1.5)	17.7 (1.8)	19.8 (2.4)	15.6 (2.1)	17.5 (2.5)	19.5 (3.3)	15.8 (1.8)	17.6 (2.2)	19.7 (2.8)
Body mass index (kg/m2)	15.8 (0.9)	15.5 (1.0)	15.3 (1.2)	15.7 (1.2)	15.4 (1.2)	15.2 (1.5)	15.8 (1.1)	15.4 (1.1)	15.3 (1.3)
Handgrip strength right (kg)	7.1 (1.9)	10.4 (1.4)	12.2 (1.6)	6.2 (2.1)	9.2 (1.9)	10.7 (1.8)	6.7 (2.1)	9.8 (1.8)	11.5 (1.8)
Handgrip strength left (kg)	6.5 (1.7)	9.4 (1.5)	11.0 (1.7)	5.5 (2.1)	8.3 (1.9)	9.7 (1.7)	6.0 (2.0)	8.9 (1.8)	10.4 (1.8)
Handgrip strength, average (kg)	6.8 (1.7)	9.9 (1.4)	11.6 (1.5)	5.8 (2.0)	8.7 (1.8)	10.2 (1.7)	6.4 (1.9)	9.4 (1.7)	10.9 (1.7)
Correlation coefficient of handgrip strength (r value)									
First year vs. Second year	Right 0.38, Left 0.48, Average 0.44			Right 0.59, Left 0.57, Average 0.59			Right 0.49, Left 0.56, Average 0.55		
Second year vs. Third year	Right 0.76, Left 0.79, Average 0.81			Right 0.84, Left 0.74, Average 0.83			Right 0.81, Left 0.77, Average 0.82		

Results are expressed as mean and standard deviation and 0.560 (95% CI: 0.513, 0.607) in boys and 0.623 (95% CI: 0.574, 0.672) and 0.597 (95% CI: 0.548, 0.646) in girls, respectively.

DISCUSSION

This study examined how children's HGS was tracked for two consecutive years before elementary school using two different methods: Spearman correlation coefficients (r) and Foulkes and Davies' tracking index (γ). We compared the results with studies of school-age children and adolescents[13,14,17], as there have yet to be tracking studies of HGS in preschool children[18].

Previously, Janz et al.[13] reported the stability of HGS assessment across the 5-year study period in American schoolchildren who were 10 years old at baseline. The authors found that the Spearman correlations ranged from 0.68 to 0.89, with no sex difference (61 boys and 57 girls). Da Silva et al.[14] reported that the correlation coefficient for HGS in school girls aged 8, 10, and 12 was 0.734 (n=94), 0.872 (n=81), and 0.872 (n=85) follow-up three years, respectively. Further, Sasayama and Adachi[17] also conducted a 3-year follow-up study of HGS in Japanese elementary school children and reported that the Spearman correlation coefficient was 0.52 for boys (n=48) and 0.68 for girls (n=43). The current study tracked children's HGS for two years before entering elementary school. The Spearman coefficient of HGS for the first year, from 4 to 5 years of age, was low to moderate (range 0.38-0.59) in boys and girls. However, there were high correlations (range 0.74-0.84) for the second year from 5 to 6 years of age, similar to the interpretation of correlation coefficients from the results of previous studies in schoolchildren and adolescents[13,14,17]. Future studies are needed to clarify the reasons for the difference in correlation coefficients between the first- and second-year changes.

Very few studies have been reported on tracking HGS indexes in children. A three-year follow-up study of Brazilian girls aged 8 to 14 reported tracking indexes of 0.713 at age 8, 0.799 at age 10, 0.741 at age 12, and 0.522 at age 14.[14] This study's tracking index ranged from 0.55 to 0.56 for boys and 0.60 to 0.62 for girls (right hand, left hand, and average hand). Considering that a tracking index of 0.5 or less means no tracking, the values in this study are interpreted as tending to be low for both boys and girls. In addition, although it may not be possible to statistically compare the values in this study with those in previous studies, the values themselves were low. These results suggest individual differences in changes in HGS during this age group and that the rank changes are high. This study does not know the factors that cause this, but in general terms, it suggests that environmental factors such as physical, mental, and cognitive development may influence changes in an individual child's HGS.

If HGS does not maintain its ranking during the two years before school entry, this suggests that even young children with low levels of HGS may be able to acquire a higher ranking (levels) of HGS by the time they enter school. Although this study did not investigate the factors that lead young children to achieve high rankings in HGS, a couple of lifestyle factors may have had an impact. For example, the influence of play inside and outside kindergartens and nurseries. We previously investigated the impact of types of play on HGS change in kindergarteners over one year but found no between-group differences based on play type (fine movement vs. gross motor movement).[19] However, because the tracking index tracks changes in each individual, it may show different results than comparing HGS changes between groups. Some children in our study enjoy playing with their hands and upper bodies, such as climbing bars or horizontal bars, and we speculate that they may experience more significant increments in HGS than other children. Moreover, the influence of nutrition on changes in children's HGS has also been noted.[20] Future research needs to clarify the level of HGS that should be achieved as a target for children at each age.

CONCLUSION

The young children's HGS obtained in the present study had low to moderate tracking results based on the numerical interpretation of correlation coefficients and tracking indexes. These results suggest that environmental factors, including physical, mental, and cognitive development, may influence changes in HGS in individual children at this age. However, the target levels at each age of young children required to achieve high HGS by adulthood are still being determined, and further follow-up studies are needed.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest regarding the research, authorship, and/or publication of this manuscript.

ACKNOWLEDGMENTS

The authors are grateful to all the children who participated in this study, their caregivers, and the kindergarten and nursery school staff (especially Ms. Rika Sanui in Atagohama Kindergarten and Ms. Natsuko Nakazato in Noko Nursery School). This work was supported by the Japan Society for the Promotion of Science, Grants-in-Aid for Scientific Research (JSPS KAKENHI Grant Number: 22K11610).

REFERENCES

1. Bohannon RW. Grip Strength: An indispensable biomarker for older adults. *Clin Interv Aging* 2019;14:1681-1691.
2. Abe A, Sanui R, Loenneke JP et al. Is the peak value truly maximal when measuring strength in young children? An updated study. *J Trainol* 2022;11:17-21.
3. Loenneke JP, Abe A, Yamasaki S et al. Sex differences in strength during development: Implications for inclusivity and fairness in sport. *Am J Hum Biol* 2024;36:e24152
4. Frederiksen H, Gaist D, Petersen HC et al. Hand grip strength: A phenotype suitable for identifying genetic variants affecting mid- and late-life physical functioning. *Genetic Epidemiol* 2002;23:110-122.
5. Abe T, Abe A, Loenneke JP. Handgrip strength of young athletes differs based on the type of sport played and age. *Am J Hum Biol* 2024;36:e24022.
6. Ortega FB, Silventoinen K, Tynelius P et al. Muscular strength in male adolescents and premature death: cohort study of one million participants. *BMJ* 2012;345:e7279.

7. Fraser BJ, Blizzard L, Buscot MJ et al. The association between grip strength measured in childhood, young- and mid-adulthood and prediabetes or type 2 diabetes in mid-adulthood. *Sports Med* 2021;51,175-183.
8. Leong DP, Teo KK, Rangarajan S et al. Prognostic value of grip strength: findings from the prospective urban rural epidemiology (PURE) study. *Lancet* 2015;386:266-273.
9. Celis-Morales CA, Lyall DM, Anderson J et al. The association between physical activity and risk of mortality is modulated by grip strength and cardiorespiratory fitness: evidence from 498135 UK-Biobank participants. *Eur Heart J* 2017;38:116-122.
10. Abe T, Machida S, Nakamura M et al. Tracking handgrip strength in kendo athletes from university to middle and older adulthood. *Am J Hum Biol* 2024;36:e24082.
11. Labott BK, Bucht H, Morat M et al. Effects of Exercise Training on Handgrip Strength in Older Adults: A Meta-Analytical Review. *Gerontology* 2019;65:686-698
12. Abe T, Thiebaud SR, Ozaki H et al. Children with Low Handgrip Strength: A narrative review of possible exercise strategies to improve its development. *Children* 2022;9:1616.
13. Janz KF, Dawson JD, Mahoney LT. Tracking physical fitness and physical activity from childhood to adolescence: the Muscatine study. *Med Sci Sports Exerc* 2000;32:1250-1257.
14. Da Silva SP, Beunen G, Prista A et al. Short-term tracking of performance and health-related physical fitness in girls: The Healthy Growth in Cariri Study. *J Sports Sci* 2013;31:104-113.
15. Abe A, Yamasaki S, Tahara R et al. Comparison of handgrip strength values in young children when using two different types of dynamometers. *Am J Hum Biol* 2022;34:e23771.
16. Foulkes MA, Davis CE. An index of tracking for longitudinal data. *Biometrics* 1981;37:439-446.
17. Sasayama K, Adachi M. Tracking of objective physical activity and physical fitness in Japanese children. *BMC Res Notes* 2019;12:252.
18. Abe T, Ozaki H, Loenneke JP et al. A longitudinal study of handgrip strength asymmetry. *Am J Hum Biol* 2022;34:e23722.
19. Abe A, Sanui R, Loenneke JP et al. One-year handgrip strength change in kindergarteners depends upon physical activity status. *Life* 2023;13:1665
20. Confortin SC, Barbosa AR, de Oliveira BR et al. The consumption of culinary preparations and ultra-processed food is associated with handgrip strength in teenagers. *Nutr J* 2022;21:66.