Tracking of Cardiorespiratory Fitness and Physical Activity from Youth to Young Adulthood: Findings from the Prospective Special Turku Coronary Risk Factor Intervention Project (STRIP)

Brooklyn J. Fraser, PhD[1], Leigh Blizzard, PhD[1], Suvi P. Rovio, PhD[2,3], Olli J. Heinonen, MD, PhD[4], Harri Niinikoski, MD, PhD[2,3,5], Jorma S. A. Viikari, MD, PhD[6,7], Tapani Rönnemaa, MD, PhD[6,7], Antti Jula, MD, PhD[8], Olli T. Raitakari, MD, PhD[2,3,9], Costan G. Magnussen, PhD[1,2,3,10,*], and Katja Pahkala, PhD[2,3,4,*]

Using data from the Special Turku Coronary Risk Factor Intervention Project, cardiorespiratory fitness (rank-order correlation coefficient = 0.60-0.62) tracked stronger than physical activity (rank-order correlation coefficient = 0.27-0.38) between youth (age = 17 years) and young adulthood (age = 26 years). Cardiorespiratory fitness could help identify individuals at risk of maintaining poor fitness levels or developing adverse health in adulthood. *(J Pediatr 2023;9:100085).*

Low cardiorespiratory fitness and physical inactivity in youth are 2 modifiable risk factors for a range of health outcomes.[1-3] The American Heart Association describes cardiorespiratory fitness as an important marker of health,[4] endorsing it as a clinical vital sign.[5] As the health benefits of cardiorespiratory fitness and physical activity begin in youth and extend into later life,[6] there are ongoing efforts to better understand how these risk factors persist, or track, from one life stage to another and to understand how they are related. Quantifying how cardiorespiratory fitness and physical activity track can inform whether strategies aimed at increasing these factors could be implemented in youth to help improve future health outcomes. To help increase current understanding, this study aims to quantify the tracking of cardiorespiratory fitness and physical activity from youth (age = 17 years) to young adulthood (age = 26 years) in a Finnish cohort.

Methods

This study uses data from the ongoing, prospective, randomized controlled Special Turku Coronary Risk Factor Intervention Project (STRIP). Additional detail regarding the study design is detailed elsewhere.[7] In summary, the STRIP began in 1990 when 1062 infants (aged 7 months) were allocated randomly to the control (n = 522) or dietary intervention (n = 540) group. The intervention group received individualized dietary and other lifestyle counseling at least biannually until the age of 20 years. The aim of these counseling sessions was to replace saturated fat with unsaturated fat and reduce cholesterol, as well as to provide guidance on how to favor whole-grain products over more refined options, and to prefer low salt use and fruits and vegetables.[7] A physically active lifestyle was encouraged, but it was not a structured, continuous part of the intervention. Counseling aimed at the prevention of smoking was introduced when children were 8 years of age.[7] The first postintervention follow-up of the participants was conducted between April 2015 and January 2018 (age = 26 years). Included in this study are those participants who provided a measure of cardiorespiratory fitness (n = 156) or physical activity (n = 328) when aged 17 years and 26 years. Of these, n = 148 had their cardiorespiratory fitness and physical activity levels measured at both time-points. The study was approved by the Joint Commission on Ethics of the Turku University and Turku University Central Hospital (now the Ethics Committee, Hospital District of Southwest Finland). Written informed consent was obtained from the children at 15, 18, and 26 years of age.

Cardiorespiratory Fitness

At both time points, the same research technician/exercise physiologist used the same maximal cycle ergometer

STRIP	Special Turku Coronary Risk Factor Intervention Project
VO_{2max}	Maximum oxygen update capacity

From the [1]Menzies Institute for Medical Research, University of Tasmania, Hobart, Tasmania, Australia; [2]Research Centre of Applied and Preventive Cardiovascular Medicine, University of Turku, Turku, Finland; [3]Centre for Population Health Research, University of Turku and Turku University Hospital, Turku, Finland; [4]Paavo Nurmi Centre, Unit of Health and Physical Activity, [5]Department of Pediatrics and Adolescent Medicine, Turku University Hospital, and [6]Department of Medicine, University of Turku, Turku, Finland; [7]Division of Medicine, Turku University Hospital, Turku, Finland; [8]Department of Chronic Disease Prevention, Institute for Health and Welfare, Turku, Finland; [9]Department of Clinical Physiology and Nuclear Medicine, Turku University Hospital, University of Turku, Turku, Finland; and [10]Baker Heart and Diabetes Institute, Melbourne, Victoria, Australia

*Contributed equally.

This work was financially supported by the Academy of Finland (grants 206374, 294834, 251360, 275595, 307996, and 322112), the Juho Vainio Foundation, the Finnish Foundation for Cardiovascular Research, the Finnish Ministry of Education and Culture, the Finnish Cultural Foundation, the Sigrid Jusélius Foundation, Special Governmental grants for Health Sciences Research (Turku University Hospital), the Yrjö Jahnsson Foundation, the Finnish Medical Foundation, and the Turku University Foundation. The authors have no conflicts of interest to disclose.

https://doi.org/10.1016/j.ympdx.2023.100085

Table I. A summary of cardiorespiratory fitness and physical activity levels and how they are correlated at age 17 years and 26 years for those included in tracking analyses

	Cardiorespiratory fitness, mL/kg/min			Physical activity, MET h/wk			Correlation between cardiorespiratory fitness and physical activity		
		Mean (SD)			Median (IQR)			r_s	
Sex	n	17 y	26 y	n	17 y	26 y	n	17 y	26 y
Sexes combined	156	41.1 (6.9)	39.1 (6.5)	328	19.6 (5.0, 52.2)	19.6 (5.0, 32.6)	148	0.41	0.55
Male	74	44.6 (6.7)	41.3 (7.2)	139	31.3 (5.0, 52.2)	31.3 (5.0, 52.2)	68	0.48	0.59
Female	82	37.9 (5.3)	37.0 (5.1)	189	19.5 (6.7, 32.6)	19.5 (5.0, 32.6)	80	0.56	0.54

MET, metabolic equivalent; r_s, rank-order correlation coefficient.

(Ergoselect 100 K; Ergoline) exercise test to estimate maximum oxygen update capacity (VO_{2max}, mL/kg/min), a measure of cardiorespiratory fitness. The test began with a workload of 50 W, which increased by 30 W (boys) and 25 W (girls) every 2 minutes until exhaustion.[8,9] During the last 4 minutes of the test, the mean workload was calculated and VO_{2max} was estimated according to the American College of Sports Medicine.[10]

Physical Activity

A self-administered questionnaire was used to assess leisure time physical activity, in which 3 separate multichoice questions inquired about the frequency (7 response options, corresponding to none, less than once a month, once a month, 2-3 times a month, once a week, 2-6 times a week, and once a day), intensity (3 response options, corresponding to light, moderate, and vigorous physical activity), and duration (4 response options, corresponding to <20, 20-<40, 40-60, and >60 minutes) of leisure time physical activity.[11] Leisure time physical activity was estimated by multiplying frequency, mean duration, and mean intensity (multiple of the resting metabolic rate, metabolic equivalent) of weekly leisure time physical activity and expressed as metabolic equivalent, h/wk.[8,9,11] The questionnaire correlates moderately well with accelerometer (r = 0.26-0.40) and pedometer (r = 0.30-0.39) data.[12]

Statistical Analysis

All statistical analyses were performed using Stata (version 17.0; StataCorp). Cardiorespiratory fitness and physical activity levels were summarized as mean (SD) or median (IQR), and rank-order correlations between both factors were estimated at 17 years and 26 years. The 9-year tracking of cardiorespiratory fitness and physical activity between the ages of 17 years and 26 years was quantified by rank-order correlations. Multiple linear regression models were used to estimate the proportion of variation in cardiorespiratory fitness levels at age 26 years explained by cardiorespiratory fitness at age 17 years and by physical activity levels across the 9-year period.

Results

Table I summarizes the cardiorespiratory fitness and physical activity levels of participants and highlights the correlations between these factors at both time points. The rank-order correlation for the tracking of cardiorespiratory fitness and physical activity between the ages of 17 years and 26 years is presented in Table II. Both cardiorespiratory fitness and physical activity tracked across the 9-year period, with coefficients stronger for cardiorespiratory fitness than physical activity. The tracking for both cardiorespiratory fitness and physical activity was consistent for both sexes. There was no statistically significant difference in tracking between the intervention and control groups (data not shown). The amount of variability in cardiorespiratory fitness levels measured at age 26 years explained by cardiorespiratory fitness levels measured at 17 years was 47.3%, with physical activity levels at both time points explaining an additional 14.5%.

Discussion

Using data from the Finnish-based STRIP study, cardiorespiratory fitness and leisure time physical activity were shown to track from youth to young adulthood across a period of 9 years for both sexes. Our findings align with previous studies,[13] where cardiorespiratory fitness, operationalized as VO_{2max}, and physical activity have been shown to track across a similar period using data from the Danish Youth and Sports Study[14,15] and the Amsterdam Growth and Health Longitudinal Study.[16,17] Collectively, these findings highlight cardiorespiratory fitness and physical activity levels in youth as potential targets to help improve one's ability to maintain favorable levels into later life, and in turn, potentially improve future health outcomes.

When comparing our results for cardiorespiratory fitness and physical activity, we found cardiorespiratory fitness to track better across this 9-year period. A similar trend was observed in the Danish Youth and Sports Study (mean age at baseline = 17.1 years) across a period of 8 years (VO_{2max} [mL/min/kg]: r = 0.35 [male], r = 0.48 [female]; VO_{2max} [mL/min]: r = 0.51 [male], r = 0.72 [female]; physical activity: r = 0.19-31 [male], r = 0.18-0.20 [female]).[14,15] The

Table II. Rank-order correlation coefficients for the tracking of cardiorespiratory fitness and physical activity between the ages of 17 and 26 years

	Cardiorespiratory fitness			Physical activity		
Sex	n	r_s	(95% CI)	n	r_s	(95% CI)
Sexes combined	156	0.60	(0.50-0.71)	328	0.33	(0.23-0.43)
Male	74	0.61	(0.46-0.77)	139	0.38	(0.24-0.53)
Female	82	0.62	(0.49-0.75)	189	0.27	(0.13-0.40)

difference between cardiorespiratory fitness and physical activity could be partially explained by cardiorespiratory fitness being an objective measure, compared with physical activity which was self-reported. Furthermore, in contrast to physical activity, which is a behavior, cardiorespiratory fitness is a phenotype made up of both behavioral and genetic components. Both components could help explain how cardiorespiratory fitness tracks and why it does so more than physical activity. We were unable to test the effect that genetics was having on the ability of cardiorespiratory fitness to track. However, given physical activity also tracked across the same period, it is likely that the tracking of cardiorespiratory fitness is not explained entirely by genetics but is likely driven by the stability in physical activity levels. This is an important note to highlight, as targeting the modifiable component of physical activity is key to improving cardiorespiratory fitness levels. Our findings showed that the proportion of variation in cardiorespiratory fitness levels in young adulthood explained by leisure time physical activity in youth and young adulthood was 14.5%. This provides a unique opportunity when considering implementing strategies aimed at targeting and improving cardiorespiratory fitness levels, as physical activity, unlike genetics, is amenable to change. Promoting a physically active lifestyle with an emphasis on educating youth of the importance of meeting physical activity guidelines[18] and arming them with age-appropriate activity recommendations could have beneficial effects on both their current and long-term cardiorespiratory fitness levels.

Limitations of this study include loss to follow-up. To account for missingness and to reduce the likelihood of bias, we repeated our analyses using a similar approach to that proposed by Seaman et al.[19] This approach includes multiple imputation to complete missing data on variables measured at age 13 months that were informative of drop out (sex, intervention status, body mass index, total cholesterol, energy-adjusted fiber and saturated fatty acid intake, and parental education and occupation status), and then used inverse probability weighting with weights based on the probability of participating in follow-up using these baseline variables. The results of these sensitivity analyses were not markedly different to those presented in our primary analyses. We were unable to quantify the tracking of maintaining high (or low) levels over time, as this analysis is not recommended when universal cut-points are lacking, as is the case for cardiorespiratory fitness among youth.[20] A strength of this study was the consistent measurement of cardiorespiratory fitness and physical activity, with cardiorespiratory fitness levels being assessed using a reliable test by the same person using the same adequate equipment at both time-points.

In conclusion, in this Finnish cohort, cardiorespiratory fitness tracked stronger than leisure time physical activity over a period of 9 years from youth to young adulthood. These findings highlight cardiorespiratory fitness as a potential early-life factor that could help identify individuals at greatest risk of maintaining poor fitness levels or developing adverse health outcomes in later life. ■

The STRIP study children and their parents and grandparents have made the study possible—the authors thank them for their time, continued efforts, and commitment to the STRIP throughout the years.

Submitted for publication Aug 26, 2022; last revision received Nov 15, 2022; accepted Feb 22, 2023.

Reprint requests: Dr Brooklyn J. Fraser, PhD, Menzies Institute for Medical Research, University of Tasmania, 17 Liverpool St, Hobart, Tasmania 7000, Australia. E-mail: fraserbj@utas.edu.au

References

1. Ortega FB, Ruiz JR, Castillo MJ, Sjostrom M. Physical fitness in childhood and adolescence: a powerful marker of health. Int J Obes 2008;32:1-11.
2. Janssen I, LeBlanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Activ 2010;7:1-16.
3. Lang JJ, Belanger K, Poitras V, Janssen I, Tomkinson GR, Tremblay MS. Systematic review of the relationship between 20 m shuttle run performance and health indicators among children and youth. J Sci Med Sport 2018;21:383-97.
4. Raghuveer G, Hartz J, Lubans DR, Takken T, Wiltz JL, Mietus-Snyder M, et al. Cardiorespiratory fitness in youth: an important marker of health: a scientific statement from the American Heart Association. Circulation 2020;142:e101-18.
5. Ross R, Blair SN, Arena R, Church TS, Despres JP, Franklin BA, et al. Importance of assessing cardiorespiratory fitness in clinical practice: a case for fitness as a clinical vital sign: a scientific statement from the American Heart Association. Circulation 2016;134:e653-99.
6. García-Hermoso A, Ramírez-Vélez R, García-Alonso Y, Alonso-Martínez AM, Izquierdo M. Association of cardiorespiratory fitness levels during youth with health risk later in life: a systematic review and meta-analysis. JAMA Pediatr 2020;10:952-60.
7. Simell O, Niinikoski H, Rönnemaa T, Raitakari OT, Lagström H, Laurinen M, et al. Cohort profile: the STRIP study (Special Turku Coronary Risk Factor Intervention Project), an infancy-onset dietary and life-style intervention trial. Int J Epidemiol 2009;38:650-5.
8. Pahkala K, Laitinen TT, Heinonen OJ, Viikari JS, Rönnemaa T, Niinikoski H, et al. Association of fitness with vascular intima-media thickness and elasticity in adolescence. Pediatrics 2013;132:e77-84.
9. Pahkala K, Hernelahti M, Heinonen OJ, Raittinen P, Hakanen M, Lagström H, et al. Body mass index, fitness and physical activity from childhood through adolescence. Br J Sports Med 2013;47:71-7.
10. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. Philadelphia: Lippincott Williams & Wilkins; 2013.
11. Pahkala K, Heinonen OJ, Simell O, Viikari JS, Rönnemaa T, Niinikoski H, et al. Association of physical activity with vascular endothelial function and intima-media thickness. Circulation 2011;124:1956-63.
12. Mansikkaniemi K, Juonala M, Taimela S, Hirvensalo M, Telama R, Huupponen R, et al. Cross-sectional associations between physical

activity and selected coronary heart disease risk factors in young adults. The Cardiovascular Risk in Young Finns Study. Ann Med 2012;44:733-44.

13. García-Hermoso A, Izquierdo M, Ramírez-Vélez R. Tracking of physical fitness levels from childhood and adolescence to adulthood: a systematic review and meta-analysis. Transl Pediatr 2022;11:474-86.
14. Hasselstrom H, Hansen SE, Froberg K, Andersen LB. Physical fitness and physical activity during adolescence as predictors of cardiovascular disease risk in young adulthood. Danish Youth and Sports Study. An eight-year follow-up study. Int J Sports Med 2002;23:S27-31.
15. Andersen LB, Hasselstrøm H, Grønfeldt V, Hansen SE, Karsten F. The relationship between physical fitness and clustered risk, and tracking of clustered risk from adolescence to young adulthood: eight years follow-up in the Danish Youth and Sport Study. Int J Behav Nutr Phys Activ 2004;1:1-4.
16. Twisk JW, Kemper HC, van Mechelen W. Tracking of activity and fitness and the relationship with cardiovascular disease risk factors. Med Sci Sports Exerc 2000;32:1455-61.
17. Twisk J, Kemper H, Van Mechelen W, Post G. Tracking of risk factors for coronary heart disease over a 14-year period: a comparison between lifestyle and biologic risk factors with data from the Amsterdam Growth and Health Study. Am J Epidemiol 1997;145:888-98.
18. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med 2020;54:1451-62.
19. Seaman SR, White IR, Copas AJ, Li L. Combining multiple imputation and inverse-probability weighting. Biometrics 2012;68:129-37.
20. Rollo S, Fraser BJ, Seguin N, Sampson M, Lang JJ, Tomkinson GR, et al. Health-related criterion-referenced cut-points for cardiorespiratory fitness among youth: a systematic review. Sports Med 2021;52:101-22.