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Cross-Country Comparisons In Health-Related Fitness Among European Children And Adolescents

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CROSS-COUNTRY COMPARISONS IN HEALTH-RELATED FITNESS AMONG EUROPEAN CHILDREN AND ADOLESCENTS

by

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Masters of Science, University of North Dakota, 2018

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Submitted to the Graduate Faculty
of the
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In partial fulfillment of the requirements

for the degree of
Masters of Science in Kinesiology

Grand Forks, North Dakota
December
2018

This thesis, submitted by Kevin Carver in partial fulfillment of the requirements for the Degree of Master of Science in Kinesiology from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

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Dean of the School of Graduate Studies

December 6th, 2018
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Date

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Department	Kinesiology and Public Health Education
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Kevin Carver
December 2nd, 2018

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ABSTRACT

Physical fitness is an important indicator of general health and sporting/athletic success. Several studies have highlighted large between-country differences in cardiorespiratory endurance, with little known about differences in other fitness components. A systematic review identified papers that reported descriptive Eurofit test results for apparently healthy (free from known disease/injury) 9- to 17-year-olds Europeans. An overall fitness index for each country was calculated as a population-weighted mean test-age-sex-specific z-score. Spearman’s correlations were used to calculate the association between country-specific fitness indices and broad socioeconomic/health indices. Performance indices were calculated for 18 countries using data collected on 2,779,165 children aged 9-17 years tested across nine Eurofit tests. The fittest children and adolescents were from Central-Northern Europe, with countries from Southern Europe demonstrating lower fitness levels. This study observed that income inequality was a moderate correlate of both musculoskeletal fitness and cardiorespiratory fitness, with higher-income countries out-performing their lower-income peers. Policies aimed at reducing the wealth gap could be a suitable population approach to improving the fitness levels of young people.

Title

Cross-country comparisons in health-related fitness among European children and adolescents

1 Introduction

Physical fitness has been shown to be an important indicator of good health, especially for predicting risks of disease, cardiorespiratory issues, and all-cause mortality (Ortega, Ruiz, Castillo, & Sjostrom, 2008). The two leading causes of mortality currently are heart disease and cancer (cdc). Ortega et al., 2008 found that several cardiovascular disease (CVD) risk factors such as high and low-density lipoprotein cholesterol, insulin resistance, blood pressure, and body fat during childhood years have been shown to tract into adulthood. Cardiovascular disease occurs more commonly later in life, but there is evidence that indicates precursors of CVD have origin during childhood and adolescent ages. The childhood and adolescent years are crucial and dramatic, consisting of physiological and psychological changes at these ages (Ortega et al., 2008).

Physical activity begins in infancy and progresses throughout adulthood. As basic movements become established and skills improve; the health, fitness, and behavioral components of physical activities increases in importance (Strong et al., 2005). A systematic review in 2005 that was sponsored by the U.S. Centers for Disease Control and Prevention (CDC) considered over 850 articles to provide a summary of the evidence of the effects of physical activity on health and behavioral outcomes such as adiposity, musculoskeletal fitness (MSF), cardiorespiratory fitness (CRF) and mental health.

Evidenced based-data are strong between beneficial effects of physical activity and MSF, several components of cardiovascular health, adiposity, and blood pressure (Strong et al., 2005).

Leukemia is the most common childhood cancer and the leading cause of cancer death among children and adolescents, specifically acute lymphoblastic leukemia. (Ortega et al., 2008). One of the problems cancer patients/survivors face is an increase in fatigue levels. Poor physical fitness has been found to be largely responsible for the disrupting symptoms of fatigue, and supervised exercise has the potential to improve a cancer patient/survivor's quality of life and overall health and well-being (Ortega et al., 2008). Improvements of CRF can also lead to improvements of psychological well-being. Possible explanations could be an improved self-image as adiposity decreases, and/or physiological factors, such as elevated levels of serotonin or endorphins that elevate mood (Ortega et al., 2008).

The influence of physical activity on anxiety and depression symptoms varies with the mode of activity, with physical activity sessions of sufficient intensity to promote an improvement in CRF also leading to a positive effect on depression status and anxiety (Ortega et al, 2008; Strong et al., 2005). Bone health and incidences of fractures are a concern world-wide, with bone mass during growing and maturation ages being of key importance to preventing osteoporotic fractures in later life (Ortega et al., 2008). As part of a systematic review, Janssen & LeBlanc, 2010 looked at a total of 11 experimental studies examining changes in bone mineral density and exercise training. Results indicated that as little as ten minutes of moderate-to-high impact activities performed only a few days a week had a modest effect on bone mineral density, when combined with other general weight bearing activities (jogging, playing, etc.), and they are also beneficial for cardiovascular risk factors and adiposity (Janssen & LeBlanc, 2010; Ortega et al., 2008).

Musculoskeletal health and fitness are important components of overall physical fitness (Strong et al., 2005) with muscular fitness (MF) having its own role to play. Findings suggest that both CRF and MF may have a combined and accumulative effect on improving cardiovascular health in children, stronger bone density later in life, and lower CVD risk factors (Ortega et al., 2008). With both CRF and MF possibly exerting a positive effect on the cardiovascular system from an early age, it is highly suggested to include physical fitness testing in health and population monitoring (Ortega et al., 2008).

Fitness testing, especially for population health surveillance or monitoring, should be valid, feasible, and scalable. While laboratory-based testing is often considered to be the most valid way of measuring fitness, it is typically expensive, requiring specialized equipment, and considerable time, and therefore is not suitable to testing large numbers of people (Castro-Pinero et al., 2009). Field testing is however a useful alternative, due to its lower cost, less expensive equipment, time efficiency, and utility for testing multiple people simultaneously (Castro-Pinero et al., 2009).

The three-main health-related components that make up physical fitness are: cardiorespiratory fitness (CRF), muscular fitness (MF), and speed/agility (Ortega et al., 2008). Ruiz et al 2010 assessed feasibility criteria of three fitness tests; endurance shuttle run (ESR) (also known as the 20-m shuttle run test, the beep test, the bleep test or the Progressive Aerobic Cardiovascular Endurance Run [PACER]), handgrip strength (HGR), and standing broad jump (SBJ). Feasibility was assessed by recording responses to items asked, such as whether the participants understood the test instructions or if the school/facility doing the testing has adequate facilities for testing. It was found that ESR was reliable to assess CRF; HGR and SBJ were reliable to assess MSF (Ruiz et al., 2010).

Since its inception in 1988, the Eurofit has been widely used to assess the physical fitness of European children and adolescents and the effectiveness of national physical education curricula (Kemper & Van Mechelen, 1996). The Eurofit comprises both health-related and skill-related fitness tests, including: (1) flamingo balance (balance), plate tapping (upper body speed), sit-and-reach (extent flexibility), standing broad jump (lower body muscular power), handgrip strength (upper body muscular strength), sit-ups (abdominal muscular endurance), bent arm hang (upper body muscular endurance), 10×5 m agility shuttle run (running speed-agility) and the 20 m shuttle run (CRF); (2) anthropometric tests measuring height, mass and skinfold (various sites) and (3) age-identification and sex-identification data (Council of Europe, 1988). Of these tests, the thee that have been shown to have the strongest link to health are the ESR, SBJ, and HGR.

International normative-referenced standards allow for comparisons to be made to a reference population to determine how well a child or adolescent compares to his/her peers. This is a commonly used approach in physical education and has been used to compare and track sports/athletes and athletic performances against centile bands to identify expected, better than expected, or worse than expected developmental changes (Tomkinson et al., 2017b).

Despite large amounts of data being generated by the Eurofit test battery since its inception in 1988 (Kemper & Van Mechelen, 1996), there was no attempt or study done to cumulate such data. Tomkinson, Olds, & Borms, 2007 "Who are the Eurofittest" study cumulated studies using the Eurofit test battery with European children and adolescents in order to describe the variability in fitness test performance among children and adolescents in Europe (Tomkinson et al., 2007). In brief; any study which used the Eurofit or provisional Eurofit test battery were considered for the meta-analysis. Only studies that had children and adolescents relatively healthy (free from disease, injuries) and none-elite were included. Studies were found from an extensive review of literature and online and CD-ROM bibliographical databases (Tomkinson et al., 2007). Of the 101 candidate studies found, 67 met the necessary inclusion criteria. All Eurofit test performances were expressed as z-scores relative to the grand mean for all children within each age X sex X test group.

For each Eurofit test, sample-weighted mean z-scores were calculated for each country across all age X sex groups for which data were available. These sample-weighted mean z-scores represent the overall standardized deviation of the fitness test performance of a country's children from European age X sex X test-specific means. The overall z-score for a country was calculated as the sample-weighted mean z-score across those tests (Tomkinson et al., 2007). Data were collected on 1,185, 656 Eurofit test performances by 7-to-18-year-old Europeans from 23 countries. Finland, Slovakia, and Iceland were the top performing countries overall (Tomkinson et al., 2007). Secondary findings of this study found that countries in Central-Northern Europe out performed their Western and Southern European peers.

Correlates of broad socioeconomic indicators, such as the HDI (Human Development Index) and the GINI Index (wealth gap/distribution within a nation) have recently been related to country-level fitness levels (Lang, Tremblay, Leger, Olds, & Tomkinson, 2016). Lang et al., 2016 reported a strong cross-sectional association between country-specific CRF and income inequality (Gini index), providing insight into potential population health programs, policies and priorities. Furthermore, a recent systematic review (Tomkinson, Lang, & Tremblay, 2017a) identified a strong negative association between country-level temporal trends in children's CRF and temporal trends in income inequality (Gini index), meaning countries with a widening gap between rich and poor residents had less favorable trends (i.e., large declines) in CRF. Other socioeconomic indices used include urbanization, climate, obesity/overweight levels, and physical activity levels (Lang et al., 2016).

This study will use normative values from the largest and most geographical representative study of physical fitness in European children and adolescents to date to analysis physical fitness in European children and adolescents (Tomkinson et al., 2017b). The primary aim of this study is to compare physical fitness levels of children and adolescents across European countries/regions. The secondary aim is to examine associations between country-level socioeconomic indices and Eurofit test performance.

2 Method

2.1 Data sources

The review protocol was prospectively registered with the International Prospective Register of Systematic Review (PROSPERO; registration number CRD42013003646). This review was conducted and reported in accordance with the Preferred Reporting Items for Systematic review and Meta-analysis Protocols (PRISMA-P) statement for reporting systematic reviews (Moher et al., 2015). A detailed description of procedures has been published elsewhere (Tomkinson et al., 2017b). In brief, a systematic review of literature was conducted to locate studies that reported descriptive Eurofit sex-age-country-year test battery data on apparently healthy (free from known disease/injury) 9- to 17-year-olds. Studies were excluded if they reported data on special interest groups (e.g., elite athletes and mentally/physically disabled) or unhealthy/injured groups and included if participants were broadly representative of their source population (Tomkinson et al., 2017b).

2.2 Inclusion/exclusion criteria

As described in Tomkinson et al., 2017b, studies were included if they clearly reported descriptive Eurofit data at the test-sex-age-country-year level, if participants were apparently healthy (free from known disease or injury) 9- to 17- year-old Europeans, and if the participants broadly represented their source population. Only studies that reported ESR, SBJ, and HGR data were included for further analysis. Studies were excluded if they reported descriptive data for sample sizes less than 20, duplicate data published in another included study, or only used special interest groups atypical of their source population.

2.3 Standardization of data and statistical analysis

As detailed in Tomkinson et al., 2017b, all descriptive data were extracted into Excel (Microsoft Office 2010, USA) using a standardized data extraction table. Descriptive data were extracted by one author and checked for accuracy by another. All data were examined for anomalies by running range checks and examining sex- and age-specific scatter plots. Only data on 9- to 17-year-olds inclusive were retained for further analysis. Data were combined from different studies and all Eurofit data were standardized to a common metric and protocol. Measurement units reported in the Eurofit handbook were used as the test-specific common metrics and for the presentation of normative centiles.

To compare Eurofit test performances for HGR, SBJ and ESR across countries, sample-weighted mean and standard deviation performance values were calculated for each test-sex-age-country group and used to calculate test-sex-age-country-specific mean z-scores using the European performance norms reported by Tomkinson et al. (2017).

$$\text{Mean z-score} = \sum(X - \mu)/\sigma$$

where X is the country sample-weighted mean test-sex-age-specific performance score, μ is the European mean performance score for the given test-sex-age-specific group, and σ is the European standard deviation for the given test-sex-age-specific group (see Table 1).

Table 1. Mean performance sample-weighted test-sex-age-country z-scores

SBJ

Country	**9F**	**10F**	**11F**	**12F**	**13F**	**14F**	**15F**	**16F**	**17F**
	x	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Austria					0.72	0.24	-0.13	0.09	
Belgium	0.41	0.34	0.25	0.32	0.29	0.34	0.40	0.43	0.43
Estonia	0.33	0.37	0.82	0.69	0.70	0.81	0.92	0.86	0.92
France	0.59	0.50	0.25	0.04	-0.27	-0.36	-0.66		
Germany				0.56	-0.65	-0.23	0.40	-0.49	
Greece	-0.56	-0.72	-0.85	-1.20	-1.29	-1.31	-1.38	-1.60	-1.45
Hungary				0.92	0.60	0.17	0.61	0.07	
Iceland	1.25	1.28	1.18	1.37	1.36	1.43	1.45		
Italy	-0.84	-0.72	-0.18	-0.31	-0.20	-0.27	-0.24	-0.42	-0.10
Latvia	0.27	0.17	0.10	0.01	0.16	0.32	0.34	0.43	0.59
Lithuania			0.41	0.37	0.48	0.57	0.66	0.61	0.65
Netherlands				0.24	0.29	0.25	0.16	0.19	
Poland	0.12	0.27	0.20	0.24	0.35	0.45	0.47	0.44	0.37
Portugal	-0.15	-0.63							
Slovakia	0.25	0.32	0.45	0.76	0.68	0.79	0.80	0.86	0.75
Spain	-0.41	-0.33	-0.11	-0.06	-0.10	0.01	0.02	0.07	0.06
Sweden					0.00	0.39	0.09	-0.05	
UK	-0.05	-0.32	-0.40	-0.52	-0.39	-0.27	-0.34	-0.28	-0.28
Country	**9M**	**10M**	**11M**	**12M**	**13M**	**14M**	**15M**	**16M**	**17M**
	x	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Austria					0.44	0.54	0.20	0.10	
Belgium	0.38	0.34	0.15	0.21	0.20	0.21	0.25	0.25	0.22

Estonia	0.13	0.41	0.62	0.58	0.59	0.65	0.92	0.80	0.72
France	0.52	0.54	0.28	0.13	-0.02	-0.04	-0.21		
Germany				0.30	-0.41	-0.30	0.28	0.03	
Greece	-0.70	-0.84	-1.00	-1.34	-1.11	-1.25	-1.51	-1.70	-1.69
Hungary				0.65	0.55	0.50	0.30	0.20	
Iceland	1.10	1.06	0.87	0.88	1.03	1.09	1.01		
Italy	-0.50	-0.36	0.15	-0.18	-0.10	-0.27	-0.43	-0.38	-0.39
Latvia	0.25	0.23	0.00	0.00	0.20	0.32	0.26	0.41	0.51
Lithuania			0.48	0.39	0.50	0.60	0.62	0.66	0.66
Netherlands				0.15	-0.03	-0.20	-0.20	-0.15	
Poland	0.11	0.16	0.08	0.07	0.23	0.33	0.35	0.38	0.38
Portugal	-0.11	-0.33							
Slovakia	0.35	0.42	0.47	0.44	0.47	0.71	0.65	0.62	0.65
Spain	-0.36	-0.31	-0.18	-0.14	-0.12	0.02	0.15	0.14	0.07
Sweden					0.78	0.72	0.50		
UK	-0.05	-0.42	-0.43	-0.54	-0.22	-0.33	-0.30	-0.13	-0.20

SBJ=standing broad jump

HGR

Country	**9F**	**10F**	**11F**	**12F**	**13F**	**14F**	**15F**	**16F**	**17F**
	x	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Austria					0.27	0.07	-0.02	-0.19	
Belgium	0.66	0.67	0.55	0.33	0.13	0.11	0.28	0.36	0.50
Estonia	0.78	-0.34	-0.51	-0.62	-0.84	-0.51	-0.35	-0.15	-0.14
France	0.19	-0.36	-0.44	-0.31	-0.36	-0.16	-0.24		
Germany					0.89	1.06	0.80	0.56	
Greece	-0.50	-0.22	-0.13	-0.08	-0.20	-0.45	-0.48	-0.28	-0.31
Hungary					0.20	-0.15	-0.10	-0.27	
Iceland				0.42					
Italy				-0.37	-0.44	-0.44	-0.31	-0.15	-0.39
Latvia	-0.21	-0.09	-0.07	-0.14	-0.30	-0.19	-0.19	-0.08	0.01
Lithuania			0.56	0.48	0.30	0.06	-0.04	0.31	0.23
Netherlands				1.02	0.63	0.58	0.81	0.84	
Poland	-0.22	0.01	0.05	0.09	-0.17	-0.22	-0.39	-0.28	-0.26
Portugal		0.39							
Slovakia	1.76	1.51	1.07	0.75	0.27	0.94	0.91	1.01	0.60
Spain	-0.18	-0.04	0.23	0.13	-0.09	-0.18	-0.17	-0.05	-0.16
Sweden		-0.34			-0.18	0.01	0.18	0.10	

UK	0.08	-0.12	0.21	-0.22	-0.27	-0.18	-0.07	0.09	0.16

Country	**9M**	**10M**	**11M**	**12M**	**13M**	**14M**	**15M**	**16M**	**17M**
	x	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Austria					0.39	0.13	0.24	0.12	
Belgium	0.60	0.82	0.76	0.36	0.20	0.16	0.19	0.36	0.43
Estonia	1.26	0.81	0.42	-0.17	-0.28	-0.19	-0.18	0.39	0.33
France	0.01	-0.10	-0.48	-0.20	-0.10	-0.27	-0.10		
Germany					0.42	0.86	0.52	0.81	
Greece	-0.44	-0.12	-0.10	-0.25	0.01	-0.19	-0.43	-0.24	-0.22
Hungary					0.28	0.29	0.45	0.31	
Iceland				0.35					
Italy				-0.42	-0.46	-0.47	-0.35	-0.39	-0.37
Latvia	-0.22	-0.09	-0.10	-0.14	-0.34	-0.41	-0.37	-0.28	-0.48
Lithuania			1.00	0.59	0.35	0.09	0.48	1.06	0.82
Netherlands				0.98	0.37	0.27	0.48	0.83	
Poland	-0.07	0.15	0.20	0.14	0.04	-0.01	-0.08	0.07	0.15
Portugal		0.38							
Slovakia	1.63	1.72	1.48	1.10	0.64	1.00	0.78	0.60	0.32
Spain	0.00	-0.04	0.19	0.18	-0.01	-0.02	-0.19	-0.18	-0.22
Sweden		-0.20			-0.22	0.34	0.31	0.17	
UK	-0.11	-0.36	-0.06	-0.37	-0.33	-0.50	-0.32	-0.15	0.12

HGR = handgrip strength

ESR

Country	**9F**	**10F**	**11F**	**12F**	**13F**	**14F**	**15F**	**16F**	**17F**
	x	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Austria					-0.04	-0.32			
Belgium	-0.10	-0.10	-0.07	0.10	0.01	0.04	0.22	0.06	0.05
Estonia	1.11	1.13	1.46	1.22	1.30	1.54	1.49	1.60	1.55
France	0.76	0.66	0.14	0.19	0.00	0.24	-0.06		
Germany				0.50	-0.56	-0.22	0.23	-0.41	
Greece	-0.55	-0.52	-0.53	-0.49	-0.52	-0.58	-0.51	-0.59	-0.53
Hungary				0.97	-0.44	0.05	0.32	-0.16	0.28
Iceland	1.37	1.47	1.53	1.72	1.44	1.44	1.55		
Italy				-0.26	-0.32	-0.28	-0.49	-0.59	-0.51
Latvia	-1.27	-0.95	-1.09	-0.98	-0.74	-0.74	-0.74	-0.39	-0.56
Lithuania			0.08	0.11	0.22	0.19	0.20	0.16	0.20
Netherlands				-0.05	0.07	0.07	0.01	0.13	

Poland	-0.43	-0.10	-0.13	-0.02	0.07	0.17	0.17	0.18	0.15
Portugal		-0.70							
Slovakia	-0.08	0.06	-0.14	0.11	-0.16	0.00	0.19	0.44	0.33
Spain	-0.39	-0.18	-0.08	0.04	0.06	0.14	0.18	0.11	0.07
Sweden					0.20	0.07	0.04	0.06	
UK	0.02	-0.13	-0.03	-0.07	0.25	0.23	0.09	0.27	0.27
Country	**9M**	**10M**	**11M**	**12M**	**13M**	**14M**	**15M**	**16M**	**17M**
	x	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Austria					-0.53	-0.26	-0.91	-0.57	
Belgium	0.03	-0.01	0.04	0.11	0.09	0.11	0.27	0.28	0.11
Estonia	0.60	0.64	0.89	0.91	0.80	0.98	1.07	1.30	1.08
France	0.45	0.61	0.33	0.15	0.27	0.38			
Germany				0.38	-0.38	-0.23	0.20	-0.52	
Greece	-0.55	-0.49	-0.45	-0.45	-0.46	-0.37	-0.40	-0.38	-0.60
Hungary				0.43	-0.33	-0.16	-0.36	-0.66	
Iceland	0.91	0.97	0.98	1.08	0.82	0.78	0.94		
Italy				-0.42	-0.27	-0.29	-0.36	-0.30	-0.32
Latvia	-1.19	-1.05	-0.95	-1.00	-0.88	-0.74	-0.82	-0.51	-0.99
Lithuania			-0.01	-0.04	0.08	0.00	0.06	0.05	-0.01
Netherlands				0.11	0.01	-0.04	0.04	0.23	
Poland	-0.53	-0.38	-0.29	-0.22	-0.11	-0.09	0.01	0.00	-0.08
Portugal		-0.65							
Slovakia	-0.19	-0.24	-0.31	-0.10	-0.15	0.09	0.50	0.64	0.51
Spain	-0.24	-0.18	-0.07	-0.05	0.10	0.18	0.22	0.12	-0.07
Sweden					0.45	0.31	-0.22		
UK	0.15	-0.05	0.08	-0.02	0.38	0.38	0.40	0.54	0.58

ESR=endurance shuttle run

Positive z-scores indicated that fitness-performances were better than the European mean and negative z-scores that fitness-performances were worse than the European mean. Population-weighted mean z-scores and corresponding 95% confidence intervals were calculated for each country, across all test-sex-age groups for which data were available, using a post-stratification population-weighting procedure described by Levy and (Levy & Lemeshow, 2008). Population estimates were extracted from the United

Nations World Population Prospective report and standardized to the year of 2000 (United Nations, 2017) — the approximate mid-year of all country-level testing periods (Lang et al., 2016). These population-weighted z-scores represented the country-specific performance index (i.e., the overall standardized deviation of a country's Eurofit performance for children and adolescents from the European test-age-sex-specific means). The indices served as a method to rank and compare the overall performance of each country.

2.4 Socioeconomic correlations

As a secondary objective, correlates between HGR, SBJ, and ESR and broad country-level socioeconomic indices were explored. Following the recommendations of Lang et al. (2016), the following socioeconomic indices were used: Over-weight and obesity rates, Human Development Index (HDI), Gini Index, Urbanization, Moderate-Vigorous Physical Activity rates (MVPA), Vigorous Physical Activity rates (VPA), and Mean Climate (Gini, HDI, Urban, Weather, WHO). Associations between the Eurofit performances and socioeconomic indices were quantified using Spearman's rank correlation coefficient with the 95% confidence limits calculated using Fisher's *z*-transformation. Correlations of 0.1, 0.3, 0.5, 0.7 and 0.9 were used as thresholds for weak, moderate, strong, very strong and nearly perfect respectively, with correlations <0.1 considered to be trivial.

3. Results

Figure 1 describes the identification of the included studies. 638 references were identified from database and grey literature search. After an initial title and abstract review, 240 were kept for full review. Following previously described exclusion criteria, 155 studies were excluded with 85 being retained for analysis. Counting all nine Eurofit tests, 2,779,165 Eurofit performances were found. Adjusting for using SBJ, HGR and ESR; 1,084,115 performances were found, representing 18 European countries, approximately 45% of EU countries (United Nations, 2017**)** and 80.63% of EU landmass (Landmass).

3.1 Country rankings by test

The performance index values for each of the 18 countries are presented in Table 2 along with their respective 95% confidence interval and percentile rank. For SBJ, Iceland was the top performing with a z-score of 1.17, and Greece was the lowest performing with a score of -1.23. For HGR, Slovakia was the top performing country with a z-score of 0.99, and Italy the poorest performing at -0.38. For ESR, Iceland was the top performing with a z-score of 1.21, and Latvia was the lowest performing with a score of -0.86. Performance indices ranged by 2.4, 1.4 and 2.1 SDs for SBJ, HGR and ESR respectively. Using the 45th north parallel to divide Europe into two segments — Central-Northern Europe (above the 4th) and Southern Europe (below the 45th) — a performance gradient similar to those observed by Lang et al. (2017) and Ortega et al. (2014) exists where Central-Northern European countries (mean±95%CI: 0.34 0.38±0.30

[SBJ], 0.23 0.29±0.17 [HGR], and 0.11 0.15±0.06 [ESR]) consistently outperformed Southern European countries (mean±95%CI: -0.47 -0.43±-0.51 [SBJ], -0.07 -0.02±-0.11 [HGR], and -0.42 -0.38±-0.45 [ESR])

Table 2. Population-weighted mean country-specific z-scores rank ordered from best to worst performing with 95% Confidence interval and Percentile Rank.

	SBJ				
Country	**x**	**SE**	**UCL**	**LCL**	**%**
Iceland	1.16	0.01	1.18	1.14	87
Estonia	0.67	0.01	0.69	0.65	75
Slovakia	0.59	0.01	0.61	0.57	72
Lithuania	0.55	0.01	0.56	0.53	71
Hungary	0.46	0.04	0.53	0.39	68
Sweden	0.37	0.07	0.52	0.23	64
Belgium	0.30	0.01	0.31	0.29	62
Poland	0.29	0.00	0.29	0.28	61
Austria	0.28	0.06	0.39	0.17	61
Latvia	0.25	0.01	0.28	0.23	60
France	0.09	0.01	0.11	0.06	53
Netherlands	0.07	0.02	0.11	0.03	52
Germany	-0.04	0.03	0.01	-0.09	48
Spain	-0.07	0.01	-0.06	-0.08	47
Portugal	-0.28	0.06	-0.17	-0.39	39
UK	-0.30	0.01	-0.29	-0.31	38
Italy	-0.31	0.01	-0.29	-0.33	38
Greece	-1.22	0.00	-1.21	-1.23	11
	HGR				
Country	**x**	**SE**	**UCL**	**LCL**	**%**
Slovakia	0.98	0.01	1.01	0.95	64
Germany	0.71	0.05	0.81	0.61	60
Netherlands	0.67	0.02	0.71	0.62	58
Lithuania	0.45	0.02	0.48	0.41	58
Iceland	0.43	0.14	0.70	0.15	55

Portugal	0.41	0.06	0.53	0.30	52
Belgium	0.41	0.01	0.43	0.40	52
Hungary	0.10	0.05	0.19	0.01	51
Austria	0.09	0.05	0.18	0.00	50
Sweden	0.01	0.02	0.03	0.05	46
Estonia	-0.03	0.02	-0.01	-0.07	46
Poland	-0.05	0.00	-0.04	-0.05	34
Spain	-0.05	0.01	-0.04	-0.07	34
UK	-0.14	0.01	-0.13	-0.15	34
France	-0.20	0.03	-0.14	-0.27	33
Latvia	-0.21	0.01	-0.19	-0.23	25
Greece	-0.26	0.01	-0.23	-0.28	24
Italy	-0.37	0.01	-0.35	-0.40	16
			ESR		
Country	**x**	**SE**	**UCL**	**LCL**	**%**
Iceland	1.16	0.01	1.18	1.13	87
Estonia	1.10	0.01	1.12	1.08	86
France	0.29	0.01	0.32	0.27	61
UK	0.15	0.01	0.16	0.14	56
Sweden	0.13	0.08	0.28	-0.03	55
Lithuania	0.08	0.01	0.09	0.07	53
Slovakia	0.07	0.01	0.10	0.05	53
Belgium	0.04	0.01	0.05	0.03	51
Netherlands	0.04	0.02	0.08	0.00	51
Spain	-0.02	0.01	-0.01	-0.04	49
Hungary	-0.03	0.03	0.02	-0.08	49
Poland	-0.11	0.00	-0.10	-0.11	46
Germany	-0.12	0.03	-0.06	-0.18	46
Italy	-0.39	0.01	-0.36	-0.41	35
Austria	-0.44	0.07	-0.31	-0.57	33
Greece	-0.52	0.00	-0.52	-0.53	30
Portugal	-0.74	0.05	-0.65	-0.83	23
Latvia	-0.89	0.01	-0.86	-0.91	19

SBJ=standing broad jump; HGR=handgrip strength; ESR=endurance shuttle run; x=mean z-score; SE=standard error; UCL=upper confidence limit; LCL=lower confident limit; %=percentile.

3.2 *Correlates of socioeconomic indices and SBJ, HGR, and ESR*

Seven socioeconomic indices were correlated with SBJ, HGR, and ESR performance scores (Table 3). The Gini index was a moderate negative correlate of fitness-performance; meaning that country-level fitness-performance decreased as the gap between rich and poor people increased. Overweight and obesity (OWOB) was a weak to moderate negative correlate of fitness-performance climate was a moderate to very strong negative correlate of fitness-performance; and vigorous physical activity (VPA) was a weak to strong positive correlate of fitness-performance.

Table 3. Spearman’s rank correlation coefficients (95% confidence interval) between 20mSRT (ESR), HGR, and SBJ performance index and socioeconomic indicators

SBJ

OWOB	95%CI	**HDI**	95%CI	**GINI**	95%CI	**Urban %**	95%CI	**MVPA**	95%CI	**VPA**	95%CI	**Mean Climate**	95%CI
-0.38	0.90	-0.24	1.22	-0.48	0.72	-0.01	2.90	0.30	1.07	0.13	1.59	-0.79	0.27

HGR

OWOB	95%CI	**HDI**	95%CI	**GINI**	95%CI	**Urban %**	95%CI	**MVPA**	95%CI	**VPA**	95%CI	**Mean Climate**	95%CI
-0.41	0.84	0.07	1.94	-0.48	0.72	-0.09	1.8	0.37	0.92	0.44	0.79	-0.31	1.05

ESR

OWOB	95%CI	**HDI**	95%CI	**GINI**	95%CI	**Urban %**	95%CI	**MVPA**	95%CI	**VPA**	95%CI	**Mean Climate**	95%CI
-0.20	1.33	0.30	1.07	-0.37	0.92	0.51	0.67	0.14	1.54	-0.01	2.90	-0.46	0.76

Note: OWOB=overweight/obesity levels; HDI=Human Development Index; MVPA=Moderate to Vigorous Physical Activity; VPA=Vigorous Physical Activity

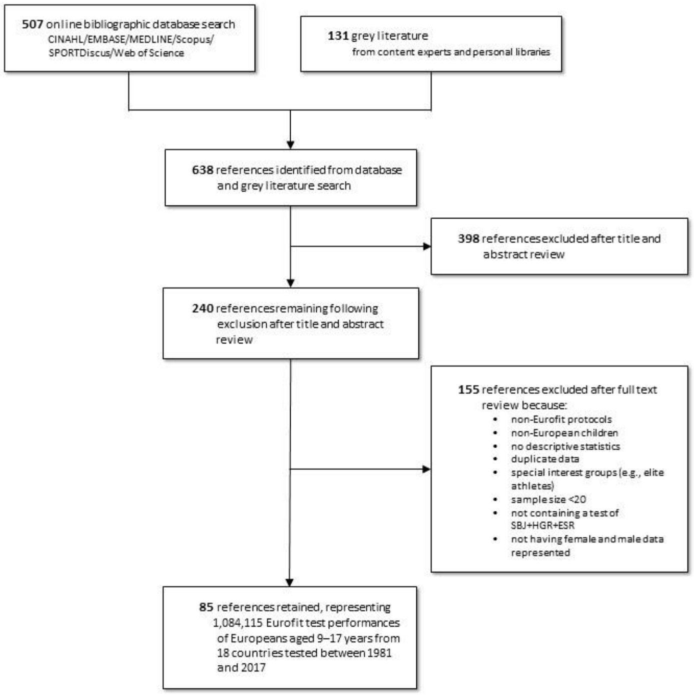

Figure 1. Prisma Flow. Steps and inclusion/exclusion criteria used.

4. DISCUSSION

This study represents one of the largest regional surveillance efforts to describe the muscular and cardiorespiratory fitness of European children and adolescents across 18 countries, albeit 18 high-income countries. The primary aim of this study was to compare physical fitness levels of children and adolescents across different European countries/regions, and to explore associations between broad country-specific socioeconomic, environmental and health indices and fitness-performance.

4.1 Regional variability in MSF and CRF

The fitness-performance of 18 high-income European countries were analyzed in this study. The main findings indicate a latitudinal gradient where Central-Northern European children and adolescents tended to have better MSF and CRF than their Southern Europe peers. This gradient was also previously described by Ortega et al. 2014 and Lang et al. 2016, both of whom observed that children and adolescents from Central-Northern European countries had substantially better static strength (Ortega et al., 2014), explosive strength (Ortega et al., 2014), speed-agility (Ortega et al., 2014) and cardiorespiratory fitness (Lang et al., 2016; Ortega et al., 2014).

4.2 Possible socioeconomic correlates

While this study examined numerous relationships between country-level fitness-performances and broad socioeconomic/environmental/health indices, for the sake of parsimony, only indices that were substantially related (rho>0.1) to both MSF and CRF are discussed (i.e., overweight/obesity levels, GINI, HDI, VPA and mean climate).

4.3 Gini index

This study observed that income inequality was a moderate correlate of both MSF and CRF, and assuming the link is causal, then policies aimed at reducing the wealth gap could be a suitable population approach to improving the fitness levels of young people. These findings are consistent with those of others, who have found that income inequality is a moderate to strong correlate of children's CRF, both cross-sectionally (Lang et al., 2016) and longitudinally (Tomkinson et al., 2017).

4.4 Physical activity and overweight/obesity levels

The prevalence of overweight and obesity in children and youth varies substantially across countries. Although there was no information on the domain in which physical activity occurred, it was anticipated that higher population levels of MVPA might have resulted in better fitness in children and adolescents, especially higher VPA levels resulting in better CRF through an improved training effect. However, physical activity is a behavior that varies substantially across time and is difficult to measure at the population level (Lang et al., 2016). This study identified a weak to strong relationship between country-level VPA and fitness-performance, suggesting that higher levels of VPA result in better fitness-performance. However, it is possible that the causal arrow points in the opposite direction; meaning that children with higher levels of fitness are more motivated to perform VPA or exercise.

This study also supports childhood overweight/obesity levels as a weak to moderate correlate of fitness-performance. Fitness and fatness can interact in many possible causal pathways. For example, increased adiposity could lead to reduced fitness-performance either directly by increasing the energy demand associated with moving a heavier body mass through space (e.g., the SBJ and ESR), or indirectly through the likely effect of reducing regular MVPA. It is also possible that children with low fitness are less motivated to exercise resulting in increased fatness. Any specific details are beyond the scope of this study.

4.5 Climate

This study indicates that climate is a moderate to very strong negative correlate of MSF and CRF. While this result is difficult to interpret, it is possible that this negative association could be explained by the physiological and/or psychological effects that occur when exercising in warm and humid climates (Lang et al., 2016).

4.6 Strengths and limitations

This study represents one of the largest and most comprehensive cross-country comparisons of fitness in European children and adolescents. This study expands on a previous article review that compared the fitness-performance of European youth (Tomkinson et al., 2007) and updates data by extending the data coverage from 2001 to 2015. Using a systematic review strategy, strict inclusion/exclusion criteria, and rigorous data treatment procedures, this study examined cross-country differences in 1,084,115 children and adolescents from 18 high-income European countries. However , there are several limitations: (a) data were pooled from studies using different sampling methods and sampling frames, and collected data across different testing conditions; (b) the vigorous nature of the Eurofit may have resulted in difficulties in testing, or exclusion of, children with a lower level of physical function; (c) unmeasured confounding (e.g., maturational age); (d) Eurofit data were also collected at different times over the period 1981–2015, and may be affected by temporal trends in fitness-performance (however, without the availability of temporal trend data for all included countries, temporal correction was not possible), and (e) all 18 countries were high-income European countries.

4.7 Utility of fitness as a population health indicator

Several cardiovascular disease (CVD) risk factors such as high and low-density lipoprotein cholesterol, insulin resistance, blood pressure, and body fat during childhood years have been shown to tract into adulthood (Ortega et al., 2008). Childhood and adolescence ages provide an important window for the measurement of health-related fitness, which can inform interventions, programs and policies (Lang et al., 2016). Fitness testing, especially for population health surveillance or monitoring, should be valid, feasible, and scalable. As a population health indicator, the Eurofit test battery is a useful, feasible and scalable tool, and the reported cross-country differences in fitness-performance indicate corresponding differences in population health.

4.8 Conclusion

This study demonstrates the broad utility of the HGR, SBJ and ESR as population health measures in children and adolescents. These tests are suitable for population fitness surveillance because they are valid, reliable, feasible and scalable measures. Children and adolescents in Central-Northern Europe tend to have better MSF and CRF than their Southern European peers. Country-level fitness-performances is also substantially related to the prevalence of overweight/obesity, vigorous physical activity levels, income inequality and climate. These data show the need for European fitness surveillance systems in order to monitor the fitness variability in children and adolescents across countries, providing insight into the general health and wellbeing of such populations.

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