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Health-related fitness in Chilean 8th graders

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Master of Public Health

Epidemiology

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Abstract Cover Page

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An abstract of

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of
Master of Public Health

in

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Abstract

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Background: Low cardiorespiratory fitness (CRF) and low musculoskeletal fitness (MSF) are important risk factors for future cardio-metabolic disease in adolescents, yet global physical fitness surveillance in adolescents, and all other age groups, is poor.

Goal: To describe the prevalence of low health-related physical fitness, including CRF, MSF, body mass index (BMI), and waist circumference (WC) of a large, population-based sample of 8th graders; and to identify independent physical fitness and sociodemographic correlates of each of the 4 physical fitness components.

Methods: The present cross-sectional study was based on 19,929 8th graders (median age = 14 years) in the 2011 National Education Survey (SIMCE) from all regions of Chile. CRF was assessed with the 20 m shuttle run test, MSF with standing broad jump, and body composition with BMI and WC. CRF, MSF, BMI, and WC were classified according to health-related standards. Regression adjusted for sociodemographic (age, socioeconomic status (SES), school type, urban versus rural, and region) and physical fitness characteristics.

Results: Girls had significantly higher prevalence of high-risk CRF, low MSF, and high-risk BMI than boys. Individual components of low physical fitness were significantly independently associated with each other and with many demographic characteristics. Notably, BMI and WC were significant independent correlates of CRF. BMI but not WC was a significant independent correlate of MSF. Adjusted significant declines in prevalence of low fitness by all 4 measures were observed from the highest of 5 SES groups to the lower 4. Students at private schools had significantly lower prevalence of low fitness by all 4 measures than counterparts at subsidized or public schools.

Conclusions: Prevalence of high-risk CRF, low MSF, and high-risk BMI was relatively high in the Chilean 8th graders compared with estimates of adolescent fitness from other countries, especially in girls. Higher prevalence of low health-related physical fitness in students of lower SES and non-private schools suggests opportunity for targeted intervention.

Keywords: Physical fitness; Adolescents; Obesity; Chile; Latin America; Socioeconomic status; Urban; Rural

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LITERATURE REVIEW

Introduction and definition of terms

The global obesity epidemic (1) is by now well known. *Obesity*, typically defined in adults as a body mass index (BMI) greater than 30 kg/m^2 (1), has risen in most countries since 1980, including in low-to-middle income countries (2). Of lesser scholarly and public recognition is the epidemic of physical inactivity (3) and its related counterpart, low physical fitness. *Physical inactivity* is defined (4) as an activity level insufficient to meet present recommendations: the World Health Organization (WHO) (5) and U.S. Department of Health and Human Services (HHS)(6) recommend every adult to achieve at least 150 minutes of moderate-intensity aerobic physical activity throughout the week in addition to muscle-strengthening activities on 2 or more days of the week and every children 6 years or older to achieve at least 60 minutes/day of moderate-to-vigorous physical activity). Physical activity is a broad term which includes exercise—a structured, repetitive, and purposeful form of physical activity—as well as activities of daily living, such as household chores (6). Physical activity is assessed either through questionnaires or by direct observation, such as pedometry or accelerometry (7). Physical fitness is defined as a state of being that reflects a person's ability to perform specific exercises or functions (8). Physical fitness is operationalized into six components: cardiorespiratory (i.e. aerobic) fitness, muscular strength and endurance, body composition, flexibility, and neuromotor fitness (9). By this definition, obesity, a description of body composition, is a component of fitness. The two components often prioritized (implicit in their order of appearance by the American College of Sports Medicine (9)) are cardio-respiratory fitness, which is most often indicated by maximal oxygen uptake (VO2max ($mL*kg^{-1}*min^{-1}$)) (10) and musculoskeletal fitness, which is indicated by performance in various weight-bearing (i.e. resistance) activities (9).

Contributions of obesity, physical activity, fitness to non-communicable disease risk and mortality in adults

Obesity, physical activity, and cardiorespiratory fitness are each independently linked to health outcomes. Obesity is important in the pathogenesis and progression of cardiovascular disease (reviewed in (11)) and is associated with higher overall mortality (reviewed in (12)). A 2013 systematic review confirmed that obesity is associated with higher mortality, but determined, unexpectedly, that overweight (BMI of 25-<30) is associated with significantly lower mortality (13). Physical inactivity is the fourth leading risk factor for global mortality (14) and causes 6-10% of the major non-communicable diseases (NCDs) (4) and 9% of premature mortality (4) worldwide. Low cardiorespiratory fitness is associated with cardiovascular disease and all-cause mortality (15). In fact, low cardiorespiratory fitness is as strong a predictor of cardiovascular disease risk and all-cause mortality as other well-known risk factors like high cholesterol, cigarette smoking, and high blood pressure (16). Data is less abundant for musculoskeletal fitness (9) than for cardiorespiratory fitness, but is still compelling. A 2012 review by Artero et al. (17) of the effect of muscular strength on cardiovascular risk factors and prognosis concluded that an appropriate level of musculoskeletal strength has numerous health-related implications. Specifically, observational studies suggest in middle-aged adults an independent protective effect of musculoskeletal fitness on all-cause (18) and cancer (18, 19) mortality and metabolic syndrome incidence (20). Generally, the authors conclude, the influence of musculoskeletal fitness was weakened but remained protective after controlling for cardiorespiratory fitness (17).

Of note, fitness may be more important than obesity (“fatness”) in relation to health risk. A systematic review investigating the relative health risks of fatness and low cardiorespiratory fitness (21) concluded that the risk for all-cause and cardiovascular mortality is lower among aerobically fit obese individuals compared to non-obese aerobically unfit individuals. Cardiorespiratory fitness has also been demonstrated to be more important than fatness with respect to the NCD risk factor profile (e.g. metabolic syndrome (22, 23)). Furthermore, cardiorespiratory fitness may be more important than physical activity in relation to health outcomes. Low fitness predicted all-cause mortality among men better than physical inactivity in a prospective male cohort (21, 24). A meta-analysis found a 64% decline in cardiovascular disease risk from the least to most fit, but only a 30% decline from the least to most active (25). In summary, low physical activity, obesity, and low fitness are each strong predictors of disease risk and mortality. Of the three, evidence suggests that the low cardiorespiratory fitness may be the most powerful risk factor.

Despite its importance, global surveillance of fitness is poorer than global surveillance of obesity (2) and physical activity (3). Surveillance of musculoskeletal fitness, compared with cardiorespiratory fitness, is particularly poor. Wang et al. (26), who published U.S. adult national fitness data, concluded that their report was the only nationally representative adult fitness estimates. The authors highlight the need for further fitness surveillance in other countries. In agreement, a 2013 statement from the American Heart Association (AHA) explicitly emphasized the need for a national U.S. cardiorespiratory fitness registry (27). Given NCD risk is by no means only a U.S. phenomenon (28), this need can be reasonably extrapolated to other countries.

Relationship between obesity, physical activity, and fitness in adults

Obesity and physical activity in adults

To obtain an understanding of the potential confounding pathways and interaction between obesity, physical activity, and fitness, an investigation into the bivariate association between each pair is helpful. Motivated fitness center attendees may be disappointed if physical activity was not associated with better body composition. This aspiration is, for the most part, warranted. In adults, cross-sectional studies reveal an inverse relationship between physical activity and waist circumference (WC) (29-31), BMI (30, 32), WC-and-BMI-classified central obesity (33), waist-to-hip ratio (WHR) (31), skinfold-thickness-determined percent body fat (29), abdominal fat measured via dual energy x-ray absorptiometry (DXA) (29, 34-36) and computed tomography (CT) scan (37). Dwyer et al.(30) found that the inverse association between physical activity and waist circumference is stronger than physical activity and BMI. The relatively stronger association with waist circumference is likely because waist circumference more closely approximates both total and abdominal adiposity compared with BMI (38).

This association between physical activity and obesity is less certain in prospective studies. A 2001 systematic review (39) found an inconsistent relationship between physical activity and change in fatness. A more recent systematic review of prospective studies (both observational and interventional) (40) concluded that physical activity (primarily aerobic exercise and resistance training) had a beneficial influence on visceral fat reduction. Furthermore, a subsequent systematic review of clinical trials (41) concluded that there is a dose-response relationship between aerobic exercise and visceral fat reduction among obese subjects without metabolic-related disorders. The review did not include resistance exercise. The less consistent conclusion in Fogelholm et al. (39) compared to the subsequent reviews (40,

41) is likely because in the review by Fogelholm et al. (39) adiposity was assessed by BMI whereas in the second two systematic reviews cited (40, 41), adiposity was measured directly.

Physical activity and fitness in adults

That cardiorespiratory fitness is associated with physical activity may be intuitive. This intuitive association was verified in a cross-sectional population-based sample of U.S. adults (NHANES 1999-2004) (26): on average, those who reported a high level of leisure-time physical activity (LTPA) had higher VO2max compared with those who reported no or low LTPA. LTPA in the NHANES data was standardized as metabolic equivalents (42) (MET; 1 MET = rate of energy expenditure while sitting at rest = 3.5 mL of oxygen uptake per kg per minute (5)). Because the MET aggregates physical activity intensity and volume (i.e. duration) into one metric, the NHANES data does not provide insight into an important question: does physical activity *intensity* or *volume* of physical have a larger independent contribution to cardiorespiratory fitness? Answering this question is difficult because in most studies where improved cardiorespiratory fitness is found for vigorous- compared with moderate-intensity exercise, the volume of exercise is also greater in the vigorous-intensity condition (reviewed in (9) and (43)). Nevertheless, evidence suggests that cardiorespiratory fitness is higher among those participating in vigorous-intensity exercise compared with moderate-intensity exercise, controlling for volume of exercise (reviewed in (44)). Vigorous intensity does not appear necessary to achieve substantial health benefits, however. A level of cardiorespiratory fitness associated with substantial health benefit seems to be attainable through the recommended dose of physical activity (9).

The association between musculoskeletal fitness and physical activity may also be intuitive. Meta-analyses (45-47) show that optimal gains in muscle function and size can occur with resistance training two to three times per week, which is in agreement with physical activity guidelines of muscle-strengthening activities twice a week (5, 6). Women who met these guidelines had significantly higher muscle strength than those who did not (48).

Still, cardiorespiratory and musculoskeletal fitness are not solely determined by physical activity. As with many health outcomes, genetics play a role. Genetics are attributable to between 40% and 70% of the variation in VO2max and between 30% and 90% of muscular strength variation (reviewed in (49)).

Obesity and fitness in adults

The third and last relationship to discuss is that between fatness and fitness in adults. Evidence suggests that, in men, poor cardiorespiratory fitness is associated with BMI-defined obesity (50), high waist-to-hip ratio (50), high waist circumference (31, 38), high BMI (38), and high total body fat assessed by underwater weighting (51), and, in women (52) and men (51), with high CT-assessed visceral adiposity. In adults of both genders, for a given BMI, better cardiorespiratory fitness was associated with lower visceral adiposity (53-55). Notably, BMI and waist circumference were each independently associated with CRF (38). Compared with BMI, waist circumference had a stronger explanatory power of the variation in cardiorespiratory fitness (38). The relatively stronger explanatory power of waist circumference is analogous to the previously reported conclusion by Dwyer et al. (30), which stated that physical activity is more closely associated with waist circumference than BMI.

In addition to cardiorespiratory fitness, Fogelholm et al. (38) also assessed the association between musculoskeletal fitness and obesity in Finnish men. Adjusted for BMI, physical activity, and other covariates, waist circumference had significant negative associations with vertical jump, sit-ups, push-ups, and back extension, but not grip strength. Controlling for the same variables, BMI had significant positive associations with vertical jump, push-ups, and grip strength, but not sit-ups or back extension. Fogelholm et al. (38) state that these opposing results are observed because, when adjusted for each other, waist circumference is an indicator of fat mass, whereas BMI becomes an indicator of fat-free mass. Under this assumption, fat mass was negatively associated with cardiorespiratory fitness and all muscular-strength-related fitness tests except for grip strength, whereas fat-free mass (a large proportion of which is muscle) was positively related to grip strength, leg explosive power, and arm and shoulder endurance (i.e. musculoskeletal fitness), but negatively associated with cardiorespiratory fitness (38).

Miyatake et al. (52) came to a similar conclusion in Japanese women, finding that cardiorespiratory fitness was negatively associated with CT-assessed-visceral fat. Similarly, CT-assessed visceral fat was negatively associated with weight-bearing index (WBI) (leg strength (kg)/body weight (kg)) (52). This finding is similar to the waist circumference-strength negative association found by Fogelholm et al. in that the indicator of central adiposity (visceral fat in Miyatake et al. (52); waist circumference in Fogelholm et al. (38)) was negatively associated with an adjusted (via the units of WBI in Miyatake et al. (52)) measure of strength. Without adjustment for fat (e.g. via waist circumference), BMI-defined obesity has been shown to be associated with increased (absolute) muscle strength (56, 57), but poorer performance in tasks requiring the support of the body or its projection off the ground off the ground (57, 58). In conclusion, body composition is associated with fitness in adults, and measures which more closely approximate adiposity, such as waist circumference, are more closely linked to fitness than BMI.

Contributions of youth obesity, physical activity, and fitness to non-communicable disease risk

The onset of and mortality attributable to NCDs occurs most frequently after the fifth decade of life (59). However, the NCD risk profile begins in childhood and adolescence. Children and adolescents with adverse risk profiles already show markers of sub-clinical cardiovascular disease, such as early atherosclerotic lesions (60) and increased carotid artery intima-media thickness (61, 62). Longitudinal studies show that clustered risk factors (metabolic syndrome (63) or otherwise (64)) track moderately from adolescence to adulthood. Similarly, physical activity, cardiorespiratory, and musculoskeletal fitness each track low to moderately from adolescence into adulthood (reviewed in (65)).

A systematic review by Ruiz et al. (66) investigated how fitness and body composition in childhood and adolescence each affect disease outcomes in adulthood. The review found that higher level of physical fitness (both cardiorespiratory and musculoskeletal fitness) and better body composition in childhood and adolescence are associated with a lower risk of cardiovascular disease development and mortality (66). With respect to musculoskeletal fitness, three noteworthy studies (67-69) succeeded the review by Ruiz et al.(66). All three studies found an independent and inverse association with cardio-metabolic risk and musculoskeletal fitness. Interestingly, the study based on a sample from 10 European cities (67) found a slightly stronger association between MSF and clustered metabolic risk compared with CRF, while the Norweigan study (68) found that the effect of CRF on clustered cardio-metabolic risk was stronger than MSF. Finally, the Danish study (69) is notable for its design. It was the first to prospectively—rather than cross-sectionally—conclude that lower muscular strength is independently associated with increased metabolic risk. These results essentially reinforce the conclusions of the review by Ruiz et al. (66). The systematic review (66) also concluded that improvements in physical fitness from childhood to adulthood are associated with positive changes in cardiovascular disease risk factors.

Some of the prospective cohorts (e.g. (70-73)) reviewed by Ruiz et al. (66) which demonstrated significant associations between below-eighteen obesity and adulthood cardiovascular outcomes did not control for physical activity or physical fitness. Without effective control for these two variables, which are known to be related to both obesity and disease outcomes (i.e. they are potential confounders), a conclusion of independent association may be inappropriate. Three recent systematic reviews support this skepticism. Lloyd et al. performed two systematic reviews investigating the independent associations between childhood BMI and adult cardiovascular disease risk (74) and childhood BMI and adult metabolic syndrome (75). Neither review (74, 75) found evidence to support the view that childhood obesity is an independent risk factor for the study's outcome of interest. Park et al. (76) arrived at an analogous conclusion investigating the independent association between childhood obesity and adult general morbidity and mortality. The data from these reviews suggested that observed unadjusted relationships between childhood BMI and adulthood outcomes depend on the tracking of BMI from childhood to adulthood. An alternative explanation for the lack of independent relationship might be a failure for control of physical activity and fitness across the life span.

The review by Ruiz et al. (66) did not explicitly assess the effect of childhood or adolescent physical activity on cardiovascular disease risk. Evidence suggests that cardiorespiratory fitness relates more strongly than physical activity to cardiovascular disease risk factors among children and adolescents (77, 78). This evidence, combined with the lack of independent association between childhood BMI and adult disease outcomes, suggests that fitness may be more, or at least as, important as obesity and physical activity in determining disease risk in young people. This conclusion mirrors the conclusion above for adults.

Relationship between obesity, physical activity, and fitness in youth

Obesity and physical activity in youth

The association between physical activity and body composition among children and adolescents is more contradictory than in adults, largely because of the inherent difficulty in accurately measuring physical activity in youth. Evidence appears to be stronger for a correlation between physical activity and abdominal adiposity, including waist circumference (79-84), than for BMI ((85), reviewed in (86) and (87)), though a consistent association has not been found for either assessment method. A systematic review of the associations between objectively measured habitual physical activity (through accelerometry, pedometry or heart-rate monitoring) and adiposity (most of the studies reviewed used BMI as a continuous or categorical variable) in children and adolescents found consistent evidence (38 of 47 studies) that such an association exists (88). Most of the studies in this review were cross-sectional preventing a determination of the association direction (i.e. obesity could be a determinant of low physical activity (reviewed in (89)). Providing evidence in the expected direction, six of the seven longitudinal studies concluded that that low physical activity was a determinant of body composition (88). The authors also acknowledged the possibility for publication bias (88). In a study following this review, the association between physical activity and abdominal adiposity was modified by cardiorespiratory fitness among European children and adolescents (84).

Physical activity and fitness in youth

Findings from the same study (90, 91) showed that meeting physical activity recommendations (5) was associated with significantly lower prevalence of low cardiorespiratory fitness among adolescent girls and boys. This conclusion might be expected, given the endurance trainability of youth (92). This chapter (92), which includes a systematic review, found an average net increase in VO2max of 8.6% among youth who participated in endurance training across 29 intervention studies (92), which essentially points out that low cardiorespiratory fitness in youth is largely a reversible condition through appropriate physical activity. Still, due to the difficulties of assessing physical activity at the population-level (93), the European results (90, 91) are noteworthy.

Because age-specific resistance training improves muscular strength (94), it may also seem obvious that physical activity improves muscular strength. From a population-based perspective, findings have been contradictory (95-99). Among Spanish adolescents, for example, muscular strength was associated with vigorous physical activity in males but not in females (100).

Obesity and fitness in youth

As with adults, fitness appears to be associated with adiposity in adolescents, and this association is again strongest for the most direct measurements of adiposity. A negative association between cardiorespiratory fitness in young people has been observed when body composition is assessed using sophisticated techniques (e.g. DXA-measured body fat in Spanish adolescents, controlling for physical activity (83), Spanish children (101), and US adolescents (102, 103) and children (103), magnetic resonance imaging-measured visceral adipose tissue in British young adolescents (104), and CT-assessed adiposity in U.S. children (103)). Validated against these sophisticated techniques, waist circumference is also associated with cardiorespiratory fitness (83). As with adults (53), the association between fitness and anthropometry that approximates adiposity (e.g. waist circumference and skinfold thickness) remains when controlling for BMI (79, 103, 105). Nonetheless, not all studies which seek to determine independent effects of waist circumference and BMI find a significant effect of waist circumference on fitness (106), suggesting BMI is still a valuable anthropometric correlate with fitness. Importantly, the effect of adiposity on fitness may increase with increasing childhood age (106). In general, the association of adiposity with cardiorespiratory fitness seems to be strongest when adiposity is measured directly, slightly weaker when assessed using waist circumference, and weakest when using BMI (103, 107).

The evidence is similar for musculoskeletal fitness. Weight-bearing musculoskeletal assessments, such as the standing broad jump, tend to be associated with lower adiposity (83, 101, 106, 108-110) in young people, whereas non-weight dependent muscular strength exercises, such as the handgrip strength test, are positively associated with central body fat among adolescents (108, 109, 111, 112). This trend also reflects the pattern in adults.

Fitness surveillance in adolescents

ALPHA and IOM

Given the strong evidence linking fitness to disease later in life, fitness surveillance in youth is of high public health importance. A European project (ALPHA: Assessing Levels of Physical Activity) has recognized and addressed this need. Investigators from this group assessed the reliability, feasibility, safety (113), and criterion-related validity (114) of school-based fitness tests in youth. Guided by this research, the group established recommendations for assessing, among other things, health-related physical fitness in children and adolescents at the population level (115). Health-related physical fitness, as defined by ALPHA, is “the ability to perform daily activities with vigor, and by traits and capacities that are associated with a low risk for the development of chronic diseases and premature death” (116). ALPHA provides both a long and short version of its test battery (116). Given sufficient time and resources, ALPHA recommends the long version, which includes the following assessments:

- 20 m shuttle run test to measure cardiorespiratory fitness
- Handgrip strength and standing long jump to assess musculoskeletal fitness
- Weight, height (i.e. BMI), waist circumference, and triceps and subscapular skinfold thickness to assess body composition, and
- 4x100 m shuttle run test to measure motor fitness

If time and resources are limited, ALPHA recommends the short version, which includes excludes the 4x100 m shuttle run test and the skinfold thickness tests.

Since the release of ALPHA, the U.S. Institute of Medicine (IOM) released guidelines (8) mirroring the ALPHA guidelines, with small differences. IOM divides their recommendations into “for national youth fitness surveys” and “for fitness testing in schools”. The IOM “national youth fitness surveys” recommendation is identical to ALPHA’s long version without the 4x100m shuttle run (8, 116). Analogous to ALPHA’s short version, IOM’s recommendation for fitness testing in schools excludes skinfold testing (and again has no 4x100m shuttle run test). It also excludes waist circumference.

Both the ALPHA and IOM guidelines recommend BMI and waist circumference, plus skinfold thickness tests, to assess body composition, although IOM leaves it out of their school-based recommendation. Throughout the present review, a stronger correlation between waist circumference and physical activity and waist circumference and fitness has been observed compared with BMI. Thus, it is not surprising that waist circumference is superior to BMI in determining disease risk in children (117), adolescents (118) and adults (119). This is likely because waist circumference is a closer measure of visceral fat than BMI (120), which cannot differentiate between muscle weight and fat weight. However, BMI is not always comparatively worse than waist circumference. Waist circumference performed no better than BMI in identifying the fattest boys (121) and the metabolic syndrome in Spanish adolescents (122). Moreover, as the IOM report points out (8), BMI is more feasible to implement, as waist circumference assessment requires expertise. It is thus sensible to measure both BMI and waist circumference.

Applications of fitness surveillance guidelines in other settings

That these two guidelines are in agreement underscores the need for their implementation. The IOM report urges the use of their guidelines because “the collection of fitness data nationally and in schools helps with setting and achieving fitness goals for public health at an individual and national level” (8). The report continues: “measuring fitness in national surveys and in schools with test items that have been demonstrated to be health-related, valid, reliable, and practical will generate data to increase our understanding of the importance of physical fitness in youth.” The intended audience for this IOM statement is likely the United States. The same perspective can and should be applied to other countries, many of which share characteristics of the U.S.’s NCD-related epidemiologic profile (59, 123)

The prevention of NCDs is not solely an endeavor of the rich-world, highlighted by the 2011 first-of-its-kind United Nations High Level Meeting on NCDs (124). This meeting was justified, according to recent disability-adjusted life years (DALYs) data. The 2012 Global Burden of Disease study found that over half (54%) of all DALYs were due to NCDs (59). The number one cause of DALYs worldwide is ischemic heart disease. Despite regional heterogeneity, ischemic heart disease ranks in the top five causes of DALYs in all regions of the world outside of Oceania and Sub-Saharan Africa (59). Furthermore, DALYs attributable to almost every NCD are increasing worldwide (59).

Demographic influence on obesity, physical activity, and fitness

Aggregate and individual socioeconomic status

NCDs do not only affect developed nations, nor, evidence suggests, do they or their risk factors affect only the rich within countries. A systematic review investigating socioeconomic status (SES) and obesity in adults in developing countries (125) verified the notion that obesity is no longer a disease of the rich in developing nations, as it seemed to be in 1989 (126). The review also pointed out that the burden of obesity in developing countries seems to shift towards groups with lower SES as the nation's gross national product increases, and that this shift is more prominent in women than men. In developed countries, weight gain was associated with a lower occupation status in non-black adults (127).

Evidence suggests low SES in childhood is a risk factor for morbidity later in life, including cardiovascular disease (128-130). It is therefore important to examine how SES relates to NCD risk factors. The inverse association between adiposity and SES remains, in general, in children, with variations found by age, gender, and parent weight status. In Europe, for example, social disparities in childhood obesity may be widening (131). A systematic review restricted to developed countries found greater association with SES and BMI among young children compared with adolescents (132). Notably, parental adiposity may act as both a confounder (132) and an effect modifier (133) in the pathway of SES and childhood adiposity.

The relationship between wealth and physical activity shows a pattern in aggregate, but in individuals, the association is less clear. Physical inactivity is, on average, more common in countries of high income (reviewed in (3)). In developing countries, male, young, and wealthy groups seem to be more active than are others (reviewed in (89)). In adults, (reviewed in (89)), children, and adolescents (reviewed in (86, 87)) of developed countries, associations between PA and SES have either been inconclusive or unobserved.

Fitness surveillance is less common than adiposity or PA surveillance; no SES-fitness review has been performed. In adolescents, the relationship between SES and fitness has been investigated in Portugal (134), Spain (135), and Northern Ireland (136). Results have been inconsistent. In a cohort of 8-18 year olds from Portugal, the authors found in an unadjusted analysis that higher SES was associated with lower muscular and cardiorespiratory fitness in some ages of boys, whereas girls 12-15 years old of higher SES had higher muscular strength (134). Freitas et al. (134) found that, in certain age groups, boys from low SES had better muscular and cardiorespiratory fitness, but girls from higher SES had better muscular strength. Meanwhile, Jiménez-Pavón et al. (135) found modest and fitness-test-dependent associations of high socioeconomic status with better fitness. In Spanish adolescents aged 12.5-18.5, higher SES was associated with better cardiorespiratory and musculoskeletal fitness, except for the lack of difference observed in cardiorespiratory fitness by SES (135). Finally, Mutunga et al. found that 12-15 year-olds of both sexes from Northern Ireland of higher SES had higher cardiorespiratory fitness (the study did not assess muscular strength) (136).

Place of residence: urban versus rural

A proposed contributor to rising NCDs worldwide is the global trend towards urbanization (137, 138). An investigation into NCD risk factors by urban-rural status is, therefore, of interest. This investigation is unique from the previous investigation of SES determinants and correlates of NCD risk factors. Regardless of the wealth of the country, people of all SES live in both urban and rural areas, though the proportion of wealth by place of residence varies by country.

Popkin et al. (reviewed in (139)) estimated 19% of rural women and 37% of urban women are overweight or obese. Regional heterogeneity exists within this estimate: rural women in Latin America, the Middle East, and North Africa have had much higher increases in prevalence compared to their urban counterparts (139). The review (139) observed little association between residence type and prevalence of overweight or obesity in countries with higher gross domestic product. A counterexample to the review's (139) claim is the United States, where obesity is higher in rural adults (140, 141), and children 10-17 (142), 8-10 (143) and 2-18 years old (144) compared to their urban counterparts. Consistent with the U.S., rural Canadian adolescents (145), Austrian 18 year-olds (146), and Swedish 18 year-olds (147) and 7-9 year-olds (148) had greater adiposity than their urban counterparts. On the contrary, urban children in New Zealand (149), girls in South Australia (150), 10-15 year olds in South Africa (151), 5-17 year olds in the United Arab Emirates (152), Cypriot 9-11 year olds (153), Omani adolescents (154), Mexican adolescents (155) and 6-13 year-olds (156), and Spanish 7-12 year olds and 13-16 year olds (157) are more likely to be obese than their rural counterparts. In other countries, such as Turkey (158), no significant difference was found with respect to adiposity measures across the urban-rural gradient. Clearly the pattern between place of residence and weight status in children and adolescents needs further exploration.

The association between physical activity and place of residence is similarly contradictory. Rural U.S. adults were less likely than urban (140, 159) and suburban (159) US adults to meet physical activity recommendations. In contrast, rural U.S. children aged 8-12 (143) and 10-17 (142) (who were, paradoxically, more obese (above)) were more active than their urban counterparts. In Portugal, rural boys engaged in more light PA on weekdays, but urban boys spent more time in moderate-to-vigorous physical activity on the weekend; rural girls were more active of all types across all days (160). Meanwhile, physical inactivity was higher for urban Mexican (155) and Omani (154) adolescents.

Lastly, the association between fitness and place of residence in young people has shown similar inconsistent results around the world. In the United States, urban 7th graders from Georgia (161) and elementary school children (162) had higher cardiorespiratory fitness levels compared to their rural peers. On the contrary, rural 7-12 and 13-16 year-olds from Spain (157), Australian children (163), Swiss children (164), and Omani adolescents (154), and Portuguese adolescents (160) had higher cardiorespiratory fitness than their urban peers. For other countries and for musculoskeletal fitness, the urban-rural differences were less homogenous. In the musculoskeletal fitness tests for Spanish adolescents, rural young people had a better performance in handgrip strength, but a poorer performance in sit-ups compared to their urban peers (157). In the U.S. state of Georgia, musculoskeletal fitness tests showed no difference across place of residence for 7th graders (161). In Mexico, urban children of both genders performed better in the musculoskeletal fitness tests than rural children (156). However, rural children 6-9 years old of both genders performed better in the cardiorespiratory fitness tests, whereas among 10-13 year-olds, urban girls performed better and urban boys did not perform differently, compared to rural children of the same age group (156). Similarly, rural Tswana children had superior cardiorespiratory performance (165) but inferior grip strength (166) compared to urban children. In Turkey, no difference was found between urban and rural children for cardiorespiratory fitness, but musculoskeletal fitness was higher in the rural children (158). In other countries, such as Greece (167), no significant difference was observed for any fitness test by place of residence.

Similar to the comparison of body composition and physical activity across rural or urban place of residence, the fitness differences across place of residence in young people vary greatly by country and by the component of fitness assessed. This variation may be attributable, in part, to inconsistent definitions of urbanity and rurality by each country. The inconsistent results are more likely related to the unique stage of development and consequent differences in urbanization and spatial distribution of wealth within each country.

The transition towards non-communicable diseases in Latin America

Latin America is no exception to the worldwide trend of increasing prevalence of and morbidity mortality attributable to NCDs (59). The region, like many areas of the world, is undergoing a rapid epidemiologic, demographic, and lifestyle transition (168), leading to an increase in the prevalence of NCDs and their risk factors (169). The burden of overweight and obesity now outweigh that of malnutrition in most Latin American countries (170, 171). The authors of the GBD 2012 study highlighted the stark changes in the cause of death structure in Central and tropical Latin America towards NCDs (123). Ischemic heart attack, the number one cause of DALYs in high-income North America, is also number one in Southern Latin America and tropical Latin America, and ranks second and fourth in Central and Andean Latin America, respectively (59). The region’s diabetes burden is much more similar to the developed western world (e.g. high-income North America and Western Europe) than that of low-income regions, such as Sub-Saharan Africa (59).

Despite the high and increasing burden of NCDs in Latin America, there is a disproportionate scarcity of research on NCD prevalence and prevention in the region. Hallal et al. scanned eight English-language academic journals which focus on preventive medicine, physical activity, and related topics (172). Between 2004 and 2009, only 18 of 888 (2%) articles in these journals pertained to Latin America (172), a grave disproportion given the region is home to over 8% of the world's population. There is a clear need for further research on NCD prevention in Latin America.

Chile as a case study of the epidemiologic transition

A growing economy and non-communicable disease burden in Chile

A Latin American country on the forefront of the development transition is Chile. Chile was a transition economy in the 1970s and by the 1980s had progressed to a post-transition stage (173). In the 1990s, during the country's restoration of democracy (174), Chile more than tripled its gross domestic product (GDP) per capita from $US 1,696 in 1987 to $US 5,738 in 1997 (175). The country's economy continues to grow quickly: its GDP rose 5.5% in 2012 (176). As a result of its rapid economic growth and democratization, Chile became the first (and only at time of publication) nation south of Mexico in the Western Hemisphere to accede to the Organization for Economic Co-operation and Development (OECD) in 2009 (177).

The South American country's rapid development comes with a familiar characteristic of advancing economies: a stark demographic and epidemiologic transition (178). In 1960, the country's disease burden was similar to the rest of Latin America, characterized by high infant and maternal mortality and high prevalence of malnutrition and infectious disease (179). By the 1990s, the epidemiologic profile had shifted dramatically. In 1998, Chile had an infant mortality rate of 10 per 1,000 live births (180) whereas in the rest of the Latin American region, the figure remained high, at 35.7 per 1,000 (181). Between 1970 and 1998, mortality attributable to NCDs rose from 54% to 75% (182). In 2008, the leading cause of death in Chile—like the rest of the world (123)—was heart disease (183).

Policy response to epidemiologic transition in Chile

This epidemiologic transition was noted by the Chilean government in the late 1990s, resulting in a shift in health priorities. In 1998, the National Board of Health Promotion (Consejo Nacional de Promoción de Salud), known as VIDA Chile, was established with the objective of changing the habits of the population through five priority areas: nutrition, physical activity, tobacco reduction, and psychosocial and environmental factors (184, 185). In 2000, VIDA Chile administered the first national Quality of Life and Health Survey (ENCAVI, by the Chilean acronym) (186) to establish a baseline against which to measure progress on specific health goals as part of a six-year (2000-2006) strategy (187). These goals mandated a quantifiable reduction in childhood obesity, sedentary lifestyle, and smoking (187), while elaborating on a guide for active living (188). In parallel, four health goals for the decade of 2000-2010 were established, one of which was to confront the challenges presented by the aging population and epidemiologic transition (189). Subsequently, in 2005, the Chilean Ministry of Health acted on WHO recommendations (190) and implemented the Global Strategy Against Obesity (EGO-Chile, by the Chilean acronym) (191). Furthermore, in 2006, the Chilean Ministry of Health created a division (VENT, by the Chilean acronym) with the singular goal of monitoring NCDs and their risk factors (183). After a mid-term (192) and full-term evaluation (193) of the 2000-2010 health goals, nine new strategic objectives (two of which were dedicated to NCDs and their risk factors) for the subsequent decade (2011-2020) were created (194). The Chilean government has clearly acknowledged and acted upon the country's epidemiologic transition. More detailed reviews of Chilean NCD-related health promotion policy exist elsewhere (195-197).

Prevalence and trends of obesity and physical inactivity in Chile

Despite these extensive policies targeting NCDs, a 2008 revisit of the Chilean nutrition transition (198) concluded that the nutritional status of the population has not improved. Obesity in Chile was rising before the adaptation in health policy and prevalence remains high. In fact, childhood obesity prevalence in Chile has caught up to the United States and may be surpassing it. Table 1 shows trends in child and adolescent obesity prevalence from the late 1980s to the late 1990s or 2000s in Chile compared with the United States.

Table 1. Prevalence and trends in obesity among Chilean children and adolescents compared with the United States

Chile

Age group (yr)	Sample type	Date 1	Date 2	Obesity prevalence (%) trend	Definition	Citation
6 - 8	Population-based	1987	2005	7.5% --> 18.5%	1983 WHO*	[198]
6 - 7	Population-based	1987	2000	Boys: 5.1% --> 14.7% Girls: 4.0% -->15.8%	2000 CDC/NCHS#	[199]
6 - 7	n=474 from Santiago	n/a	2010	17.5%-19.2%	2007 WHO^	[200]
M: 10 - 16 F: 12 - 6	Multiple cities	1986	1998	Adolescent boys: 1.6% --> 14.6% Adolescent girls: 2.3% --> 17.6%	2000 CDC/NCHS#	[198]

United States

Age group (yr)	Sample type	Date 1	Date 2	Obesity prevalence (%) trend	Definition	Citation
2 - 5	Population-based, NHANES III --> NHANES 1999-2000	1988-1994	1999-2000	Boys: 6.1% --> 9.9% Girls: 8.2% --> 11.0%	2000 CDC/NCHS#	[201]
6 - 11	Population-based, NHANES III --> NHANES 1999-2000	1988-1994	1999-2000	Boys: 11.6% --> 16.0% Girls: 11.0% --> 14.5%	2000 CDC/NCHS#	[201]
12 - 19	Population-based, NHANES III --> NHANES 1999-2000	1988-1994	1999-2000	Adolescent boys: 11.3% --> 15.5% Adolescent girls: 9.7% --> 15.5%	2000 CDC/NCHS#	[201]

*1983 World Health Organization recommendations [198] which were based on the 1977 U.S. National Center for Health Statistics (NCHS)

#2000 Centers for Disease Control and Prevention (CDC)/NCHS growth charts [199]

^2007 World Health Organization growth curves

Although Table 1 doesn't directly compare equivalent age groups and time periods, it remains informative in contextualizing trends in Chilean pediatric obesity prevalence. A general observable trend is that Chilean young people began the respective time intervals with less obesity and emerged with roughly equivalent or higher obesity prevalence relative to the United States. For example, from 1987 to 2000, obesity prevalence in Chilean six year old boys and girls increased from 5% to 15% and 4% to 16% (199). By the same definition of obesity prevalence (the 2000 CDC/NCHS curves (200)), obesity prevalence in U.S. 6-11 year old boys and girls increased from 12% and 11% to 16% and 15% (201).

Evidence suggests, at least in Santiago, the 6-year-old obesity prevalence has continued to increase as of 2010 (202). The pace of the rise in Chile is particularly striking. In the city-based adolescent sample, adolescent obesity was 4% and 9% in boys and girls in 1994 (data not shown in Table 1) (198). Just four years later, in 1998, as shown in Table 1, adolescent boys and girls had a 15% and 18% obesity prevalence (198). Wang et al. highlights the relative pace of the rise in childhood obesity in Chile, showing that, on an annualized basis, Chile's pace of obesity increase since 1970 exceeds, notably, the United States, Australia, and Brazil, among others (203).

Pre-2003 population-based adult Chilean obesity data is limited, but cross-sectional results from Santiago show similar temporal trends. In men and women in Santiago, obesity increased from 6% and 16% in 1987 to 16% and 24% in 1992 (198). Obesity prevalence among pregnant women in Chile increased sharply between 1987 and 2000, where it plateaued (198). The two most recent National Health Surveys (ENS, by the Spanish acronym) in 2003 and 2009 have updated this Santiago-specific data to include the entire country and indicate rise in prevalence. In 2003, obesity (BMI> 30) prevalence was 19% for men and 27% for women (204).

In 2009-2010, the prevalence rose in women to 31% while remaining essentially the same in men at 19% (205).

The two national health surveys (204, 205) also assessed adult adiposity based on waist circumference. In ENS 2009-2010 (205), the authors used three different waist circumference cut-points to classify abdominal obesity. The first cutpoint (men: 102 cm; women: 88 cm) was recommended by the U.S. National Institutes of Health (NIH) in 1998 (206), and was used in ENS 2003 (204, 205). The International Diabetes Federation recommendations (men: 94 cm; women: 80 cm, Europids) (207) was also used (205). The last classification was the most sensitive and specific criterion-referenced cutpoint in the Chilean population (205, 208, 209). The NIH definition classified 19% of men and 47% of women with abdominal obesity in 2009-2010. For comparison, the NIH definition classified 31% of white males and 44% of white women with abdominal obesity in NHANES III, 1988-1994 (210).

The high prevalence of obesity in Chile, as might be expected, is accompanied by a high prevalence of sedentary lifestyle and physical inactivity. ENCAVI 2000 reported a 91% prevalence of physical inactivity (defined as engaging in physical activity for at least 30 minutes less than three times per week) among Chileans 15 years of age and older (186). Sedentary lifestyle has thereafter decreased slightly in Chileans at least 15 years old, from 89% in 2003 (204) to 86% in 2006 (211) to 84% in 2010 (205). ENS 2009-2010 (205) also assessed physical activity using the global physical activity questionnaire (GPAQ), which defines physical inactivity by the WHO criteria (5). When defined by GPAQ, 27.1% of Chileans at least 15 years of age were physically inactive, with women being more inactive (31.7%) than men (22.2%). This figure is similar to the rest of the world and surprisingly lower than the average in the Americas.

Worldwide, 31.1% of adults are physically inactive, while 43.3% are physically inactive in the Americas (3).

Obesity prevalence is high in Chile and well-monitored in the adult population, but there is need for an updated population-based adolescent estimate of obesity prevalence.

Sociodemographic influences on health in Chile

Income equality, obesity, and physical inactivity in Chile

Chile's economy has grown rapidly, yet its income inequality remains very high. Although the country has among the lowest absolute and relative poverty rates in the Latin American region (212), in 2011, the wealthiest 10% received 38% of the income, compared to the 32% average in Latin America (212), an unequal region by global standards (213). This unequal distribution of wealth translates into the unequal distribution of health outcomes and risk factors, which was reflected in the country's health goals for the last (189) and present decade (194).

Using educational attainment as a proxy for SES, Chilean national health surveys show economic disparities in obesity and physical inactivity prevalence. BMI-defined obesity prevalence in 2003 was highest (31%) among those who only graduated from primary school, 19% among high-school graduates, and lowest (16%) among those with a college education (204). Prevalence of overweight did not vary by education level (204). The 2009-2010 ENS (205) showed similar results. BMI-defined obesity was 36% among the least educated, 25% among the middle-educated group, and 19% among the most educated (significantly lower than the lower two educational groups) (205). Abdominal adiposity (waist circumference-defined using criteria 3 in ENS) was similarly highest in the lowest educated group at 76% (205). The prevalence of abdominal obesity in the higher two educational groups was near 58% in both groups (205).

Similarly, physical inactivity prevalence was significantly the lowest among the most educated (82%), compared to 89% among the middle group and 97% among the least educated according to ENS 2009-2010 (205). The trend differs slightly under the GPAQ definition. The least educated have the highest prevalence of GPAQ-defined physical inactivity (35%), but the lowest physical inactivity was found in the middle-educated group (23%), with the highest educated group falling in between (30%) (205). Considering more than just education, ENCAVI 2006 found, similarly, that physical inactivity increased, in a dose-response pattern, down five SES quintiles, from 85% in the wealthiest quintile to 95% in the poorest (211). Although variations occur by measurement method, a general trend of increasing obesity and physical inactivity with decreasing SES is apparent in the Chilean population.

Place of residence (urban or rural), obesity, and physical inactivity in Chile

Latin America has undergone a progressive urbanization; 75% of the region's population is now urban (214). Chile is no exception and urbanized before many of its Latin American peers. The proportion of the population in urban areas steadily increased from 75% in 1970 to 86% in 1995 (215), where it has plateaued. Some have proposed that government estimates in Latin America (214), including Chile (216-219), may overestimate the proportion of the population living in urban areas, but there is little doubt that the region, including Chile, is no exception to the global urbanization trend (220).

Population-based obesity and physical activity estimates by place of residence have been performed in Chile. According to ENS 2009-2010 (205) obesity prevalence was 29% in rural areas and 25% in urban areas. The rural-urban obesity disparity is apparently wider in women than men On the contrary, no aggregate variation by place of residence is evident for abdominal (i.e waist-circumference-defined) obesity. However, men are more likely to have abdominal obesity in urban areas whereas women have a higher prevalence of abdominal obesity in rural areas (205).

Both ENCAVI 2000 (186) and ENCAVI 2006 (211) showed higher physical inactivity in rural areas (95.4% versus 88.3% in 2006), a trend consistent with the U.S. (above) (140, 159).

Overall, obesity and physical inactivity seem to be more prevalent in rural areas in Chileans at least 15 years of age.

Fitness surveillance in Latin America and Chile

A glaring omission from the discussion of the epidemiologic transition in Latin America and Chile is *fitness*. Fitness has been measured in relatively few Latin American studies (221-228). No large epidemiological study or representative sample apart from the SIMCE government report (229) has been published. In Chile, physical fitness has been assessed twice in youth (221, 222), both in the context of a school-based intervention. Bonhauser et al. (221) assessed cardiorespiratory and musculoskeletal fitness in a physical activity intervention in 9th graders in a low-income neighborhood of Santiago, concluding that the physical activity intervention group had significantly better fitness than the control group. Another Chilean school-based intervention across three cities included cardiorespiratory fitness, as assessed by the 20mSRT, as an outcome variable (222). The study similarly found that the intervention groups had significantly better fitness than the controls among the primary school children (grades 1-8) (222). Other Latin American studies measuring fitness have occurred at the U.S.-Mexico border (223), Brazil (224-228), and Colombia (230), three of which occurred in young people (223, 224, 230).

School-based interventions on fitness are promising in Chile. These studies would benefit from a population-based reference against which to compare the fitness outcomes.

Summary of identified needs

The literature review has identified multiple research needs. The global epidemiologic transition towards NCDs is no secret. Physical fitness is as strong of a predictor of NCD status later in life as obesity and physical activity, yet global fitness surveillance is poorer than surveillance of obesity and physical activity. Monitoring of musculoskeletal fitness is particularly meager, compared with cardiorespiratory fitness. The AHA call for a national fitness registry underscores this surveillance deficiency. A better understanding of how fitness is associated with different measures of body composition was explicitly called for in the IOM guidelines (8). Globally, there is an abundant, albeit contradictory, body of evidence relating socioeconomic status and urban or rural place of residence to obesity, but very little research on how these sociodemographic characteristics relate to fitness. Additionally, guidelines from a European group (ALPHA) and a United States institution (IOM) on assessing adolescent fitness were recently released and essentially came to the same conclusions. These guidelines should be implemented at the population level outside of Europe and the United States, as the rationale for their creation is not unique to Europe and the U.S.

Furthermore, despite the clear, and not terribly recent, epidemiologic transition in Latin America, there is relatively little research on NCD prevention in the region. In Chile, a country well-established in the epidemiologic transition towards NCDs, obesity and physical activity have been well-monitored by the government and research institutions. Still, adolescent obesity surveillance has been poorer than in the adult population. Moreover, neither cardiorespiratory nor musculoskeletal fitness have been assessed in Chile, or anywhere else in Latin America, at the population level in any age group.

Study Objectives

With the aim of satisfying these needs, this study has the following principal objective:

To describe the health-related physical fitness, including cardiorespiratory fitness, musculoskeletal fitness, and body composition, of a large, population-based sample of Chilean 8th graders in 2011

Aim 1

To describe the prevalence of low cardiorespiratory fitness, musculoskeletal fitness, excessive adiposity and their combination stratified by sociodemographic variables in the sample of Chilean 8th graders.

Aim 2

To identify significant correlates of low cardiorespiratory fitness, musculoskeletal fitness, and excessive adiposity, after adjusting for potential confounders in the sample of Chilean 8th graders.

METHODS

SIMCE Overview

The source of data for the present secondary analysis is SIMCE (Sistema de Medición de la Calidad de la Enseñaza; System for Measuring the Quality of Education). SIMCE is a series of annual national academic evaluations in Chilean 2nd, 3rd, 4th, and 8th graders administered by the Chilean Ministry of Education (231, 232). A subset of grade levels receives the academic test each year (i.e. not all grade levels listed get the test each year) (232). Until 2009, SIMCE only included traditional academic standardized tests in math, reading, natural sciences, and social sciences. In 2010, two tests were added: an English test among 3rd graders and a physical education test among 8th graders (229, 233). The physical education component of SIMCE was authorized by the Chilean government in the Law of Sport number 19.712 article 5 (229). The present study was considered exempt by Emory University Institutional Review Board.

The Sample

Contrary to the academic tests, which covered about 94% of the matriculated Chilean 8th grade population in 2011 (231), the physical fitness tests were administered to a large population-based sample of about 12% of the matriculated 8th grade population (229). The sample was stratified by region and school type into 45 mutually exclusive strata. Within each stratum, schools were the primary sampling unit. All students in each school were sampled. The fitness data was collected by the Chilean Ministry of Education from November 7, 2011 to November 30, 2011 (229). Each student was measured once. That is, the design of the present study is cross-sectional.

28,649 students were considered for fitness evaluation (229, 231) from all 15 regions of Chile, from 227 cities, and across all five socioeconomic quintiles (Figure 1). Due to erroneous data entry, student disability, and failure to complete all fitness tests, the Chilean Ministry of Education limited the sample to 19,929 students, the number of students available to the present authors. We then excluded students 18 years and older and with missing body mass index (BMI) measurement to arrive at a working sample of 19,904. Within the working sample, some variables had missing data. Of note, some students were excluded from the 20-meter shuttle run test (20mSRT) due to poor performance in the cafra test, a description of which can be found in the SIMCE 2011 Physical Education report (229). In brief, in the cafra test, students walked at a constant velocity of 6 km per hour around a pentagon-shaped 50 m course. If, at the end of three minutes, their heart rate exceeded 160 beats per minute, they were deemed ineligible to participate in the 20mSRT. This screening criterion resulted in a final sample of 17,928 for the 20mSRT.

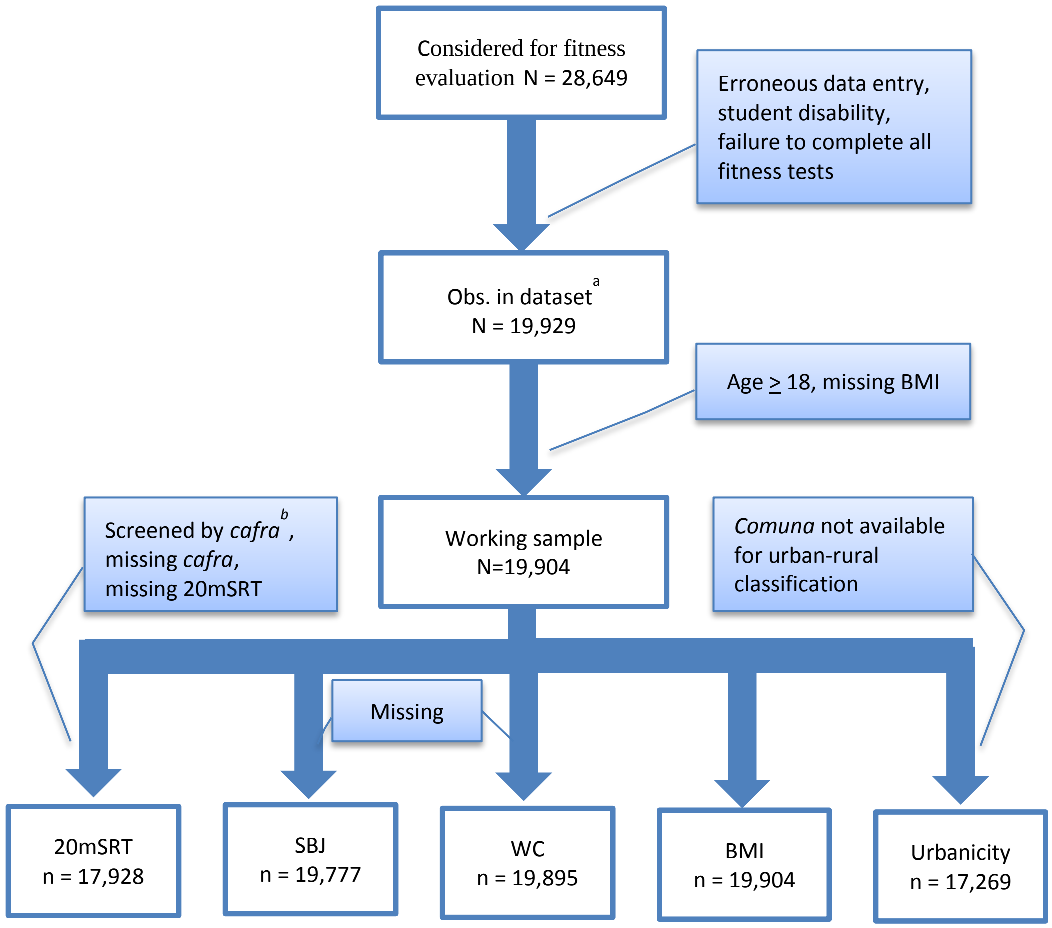

Figure 1. Flowchart of exclusions in sample of Chilean 8th graders in 2011 Physical Education Survey (SIMCE). No demographic variables besides urbanicity (shown) and SES (n=19,821) had missing values in working sample.*

**Abbreviations:* 20mSRT, 20 meter shuttle run test; SBJ, standing broad jump; WC, waist circumference; BMI, body mass index; s, second; bpm; beats per minute

[a] The dataset the investigators received from the Chilean Ministry of Education.

[b] In the cafra test, students walked at a constant velocity of 6 km/s around a pentagon-shaped 50 m course. If, after 3 min, their heart rate exceeded 160 bpm, they were ineligible to participate in the

Variable selection

The physical education test included the following body composition and fitness tests:

- BMI (weight (kg)/height^2 (m^2))
- Waist circumference
- Sit-ups
- Standing broad jump
- Push-ups
- Sit and reach test
- Cafra test
- 20 meter shuttle run (20mSRT))

Consistent with recommendations by a European academic group (ALPHA) and the U.S. Institute of Medicine (IOM) (8, 116), we restricted our analysis to health-related (66) , validated (114), and reliable (113) field-based fitness tests. *Health-related* means the test can discriminate cardio-metabolic disease risk in adolescents. *Validated* means the field-based test accurately assesses what it intends to. *Reliable* means multiple trials of the test yield similar results under the same conditions and in close temporal proximity (234). The four tests we assessed are below:

- 20 m shuttle run
- Standing broad jump
- Waist circumference (cm)
- BMI (weight (kg)/height^2 (m^2))

The 20 m shuttle run, administered as described by Leger (235), was used to estimate maximal oxygen consumption (VO_2 max), a measure of cardiorespiratory fitness. The standing broad jump, also sometimes referred to as the standing long jump, assessed musculoskeletal fitness (MSF). The only fitness assessment included on the short version of the ALPHA Health-Related Fitness Test Battery for Children and Adolescents (116), but not in the SIMCE fitness tests (229) is the handgrip test. While it would be ideal to include ALPHA's recommended test to assess upper-limb musculoskeletal fitness, Milliken et al. (236) reported a significant association between lower body explosive muscular strength and handgrip strength in children aged 7 to 12 Furthermore, Castro-Piñero et al. (237) conclude that standing broad jump could be considered as a general index of lower *and upper* body muscular fitness in youth.

We used the following demographic variables:

- Age (assessed using birth month and birth year)
- Socioeconomic status (five categories)
- Region (of 15)
- City/neighborhood (of 227)
- School type (private, public, subsidized)
- Rural versus urban *comuna* (*Comuna* is the smallest administrative subdivision in Chile)

Variable classification

All continuous variables were categorized for greater interpretability.

Health-related fitness variables classification

VO2max estimation from 20 m shuttle run

The 20mSRT was used to estimate the maximal rate of oxygen uptake (VO2max). VO2max is considered the gold standard for measurement of cardiorespiratory fitness (CRF) (10). Léger et al. (235) developed the first and most widely used equation to estimate VO2max from 20mSRT stage. Other equations to estimate VO2max have since been developed by Barnett et al. (238), Fernhall et al. (239), Stickland et al. (240), Matsuzaka et al. (241), Flouris et al. (242), Mahar et al. (2006(243) and 2011(244)), Ruiz et al. (245), and others developed in athlete-specific populations (246, 247). Many of the equations require measured speed at the end of the test (238, 241) or number of swimming-pool-like laps completed (243, 244). The present dataset measures number of stages, which are the one-minute time intervals after which the frequency of the test's noise signal increases. The two equations developed in adolescent study populations which use input variables available in the present study's dataset appear in Table 2.

Table 2. Eligible[a] equations to estimate VO2max from the 20 m shuttle run test in a 2011 population-based sample of Chilean 8th grade students

Author	Year	Sample	Age (yr.)	Inputs	Equation[b] to estimate VO2max (ml/(kg*min))
Léger et al.(235)	1988	188 boys and girls	8-19	Age, speed	VO2max = 31.025 + 3.238*S −3.248*A + 0.1536*S*A
Ruiz et al. (245)	2008	122 boys, 71 girls	13-19	Gender, age, weight, height, laps completed	Available on p. 235 of (245)

[a]Developed in an adolescent population with input variables available in SIMCE 2011 data

[b]*Variable definitions:* A is age (yr.); S is speed (km/h) (S=8+0.5*laps completed)

The validity of VO2max estimation equations relative to the Léger equation and to each other has been extensively studied in various populations (238-241, 243-245, 248, 249). In 2008, Ruiz et al. (245) found that their artificial neural network equation more accurately predicted VO2max than Léger's equation in the sample of adolescents (aged 13-19 years) studied. Ruiz et al. (245) and others (244, 249) have shown that the Leger equation underestimates VO2max more than other equations. Another often-cited limitation of the leger equation is its failure to differentiate between males and females, despite the fact that fitness performance is known to vary by gender (249). However, relative to the Leger equation, the syntax of the Ruiz equation is practically difficult (249). An advantage of the Leger equation is its wide use and consequent comparability. Despite its known shortcomings, we used the Leger equation to estimate VO2max.

VO2max classification

To classify VO2max, we used the 2011 FITNESSGRAM standards (250), which are an update to the 2008 validated (251) FITNESSGRAM standards (252). The 2011 age-and-gender-specific criterion-referenced VO2max cut-points were validated against the metabolic syndrome using nationally representative data (NHANES [1999–2000 and 2001–2002]) (250). 2011 FITNESSGRAM standards use two cut-points rather than one, allowing for the categorization of children into three groups: healthy fitness zone, needs improvement, and needs improvement-health risk (250). These three categories performed better in a sensitivity analysis compared to the previous 2008 dichotimization. The 2011 FITNESSGRAM cardiorespiratory fitness cut-points are shown below in Table 3 (250).

Table 3. FITNESSGRAM 2011 Aerobic capacity thresholds in youth aged 12-18, VO2max (mL/kg/min), adapted from (250)

	Boys		Girls	
Age (years)	At risk	HFZ*	At risk	HFZ*
12.0-12.9	37.6	40.3	37	40.1
13.0-13.9	38.6	41.4	36.6	39.7
14.0-14.9	39.6	42.5	36.3	39.4
15.0-15.9	40.6	43.6	36	39.1
16.0-16.9	41.1	44.1	35.8	38.9
17.0-17.9	41.2	44.2	35.7	38.8

*Healthy Fitness Zone

Standing broad jump classification

Criterion-referenced cut-points for musculoskeletal fitness, as indicated by standing broad jump, have not been explicitly established. Neither Ortega et al. (253), who present European percentiles for standing broad jump, from which the ALPHA cut-points (116) are based, nor Castro-Piñero et al. (237), who argue for its usefulness as an index of musculoskeletal fitness, explicitly dichotomize the standing broad jump into risk-based categories of healthy and unhealthy. Moreover, FITNESSGRAM (254) does not include cut-points for standing broad jump in youth, so its methodology cannot be used as a reference as it is elsewhere in the present analysis.

The two studies which demonstrated that standing-broad-jump-defined muscular strength was independently associated with cardiometabolic risk in adolescents (67, 68) did so by classifying standing broad jump into quartiles. The least fit quartile showed the strongest association with a poor cardiometabolic risk profile in both the HELENA (67) and the Norweigan study (68). Consequently, the lowest quartile could justifiably be considered a risk group. Conveniently, in the same study population in which the musculoskeletal fitness-cardiometabolic risk independent association was found (67), Ortega et al. present sex-and-age-specific standing broad jump percentiles in European adolescents (253). Combining the two sources, we considered the risk group to be the 20th percentile of European adolescents (253), which corresponds to the "very low" category of the standing broad jump as proposed by ALPHA (116). The selection of the 20th percentile of the HELENA study versus the 25th was chosen partly for convenience: the 25th was not presented. It is also more conservative than the 20th percentile, a rationale supported by the IOM report, which prefers to under-report than to over-report low fitness (8).

Body Mass Index Classification

In adults, the BMI cut-points of 25 kg/m2 and 30 kg/m2 to classify overweight and obesity, respectively, are well-established (1). The cut-points are shown to be highly correlated with adiposity (255-257), and approximately related to health risk (206), although a 2013 meta-analysis has called into question the disease risk among the overweight group (13). In children and adolescents, far less consensus exists regarding risk-based BMI cut-points to classify overweight and obesity (reviewed in (258)).

Even in Chile, childhood and adolescent obesity has been classified multiple ways. In the two Chilean national health surveys to date that have assessed BMI-defined obesity (186, 204), which include all Chileans 15 years or older (i.e. some adolescents), the adult cut-points (1) were used. Meanwhile, adolescent obesity has been defined (198) using the 2000 CDC/NCHS standards (200). In Chilean young elementary school children, obesity has been evaluated using five different methods. In one population-based sample of Chilean first graders (198), obesity was defined according to the 1983 WHO recommendations (259) which were based on 1977 U.S. National Center for Health Statistics (NCHS) data (259). Separately, in Santiago first graders (202), obesity was defined according to the 2007 WHO growth curves (260), which are an extension of the 1983 curves and are also based on 1977 NCHS data. Acknowledging the myriad of childhood obesity assessment methods, Kain et al. (199) compared three other methods for assessing obesity in Chilean six year olds: weight-for-height index (W-H), the International Obesity Task Force (IOTF) standards (261), and the 2000 CDC/NCHS standards (200). The highest obesity prevalence was reported using W-H, followed by 2000 CDC/NCHS (200), and the lowest by IOTF (261). Three of the aforementioned methods, plus three others, were considered to classify BMI-defined obesity in Chilean adolescents: IOTF (261), 2000 CDC (200), within-sample percentiles, ALPHA (116), WHO 2007 (260), and 2011 FITNESSGRAM (262). These methods are presented in Table 4.

Table 4. Potential methods to classify overweight and obesity from body mass index (kg/m^2) in a 2011 population-based sample of Chilean 8th grade students

Name	Year	Sample description	Development method
IOTF (261)	2000	97,876 males and 94, 851 females. 0-25 years old from 6 national samples in Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States	Statistical methods to produce smoothed percentile curves
CDC (200, 263)	2000	U.S. national data collected in 5 surveys between 1963 and 1994. 2-20 years old.	Statistical methods to produce smoothed percentile curves
Age-and-sex-specific, sample-specific percentiles	n/a	n/a – the sample of the present study	Derived from sample of present analysis. e.g. 85th-95th: overweight; >95th percentile: obese
ALPHA (116)	2010	2,160 boys and girls aged 13-18.5 years randomly sampled from locations in Spain (264)[a]	Statistical methods to produce smoothed percentile curves
WHO (260)	2007	1977 National Center for Health Statistics: U.S. national data collected in 3 surveys between 1963 and 1974 merged with data from the under-fives growth standards' cross-sectional sample (18–71 months); n=22,917	Statistical methods to produce smoothed percentile curves
FITNESSGRAM (262)	2011	U.S. National Health and Nutrition Examination Survey (NHANES) 1999-2004; n=8,269	Receiver operating characteristic (ROC) analysis to determine optimal BMI thresholds for detecting previously created %BF standards (265, 266), which predicted metabolic syndrome

[a]This sample is not used for all of ALPHA's recommendations.

The IOTF curves (261) were developed using population-based samples from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States. As was partially evident by the three-way comparison in Chilean six-year olds (199), the IOTF standards underestimate obesity prevalence in young children, but overestimate the prevalence in older children (267). Despite this limitation, the IOTF standards are widely used for international comparative purposes (267), as they represent the only international reference not solely derived from a U.S. sample. Still, the IOTF curves were not developed with health outcomes in mind, although they have been retrospectively evaluated in a sensitivity analysis based on percent body fat (268). This receiver operating characteristic (ROC) analysis reported that the IOTF BMI cutoffs successfully identified those with high body fat with high sensitivity and specificity (268).

The U.S. sample included in the IOTF data (261) is the same sample used for the 2000 CDC growth charts, without NHANES III (200). The 2000 CDC curves have been widely recommended by U.S. institutions. The Institute of Medicine, in 2005, recommended (269) classifying childhood obesity in the U.S. as > 95th percentile of CDC BMI-for-age-and-sex growth charts (200). Expanding upon those recommendations, in 2007, the American Academy of Pediatrics (270), added a BMI percentile range of 85th-95th to classify overweight status. The American Diabetes Association also recommends the 2000 CDC curves for assessment of adolescent metabolic syndrome prevalence (271). Notably, the Chilean Ministry of Health recommends the 2000 CDC curves to assess adolescent health (272), as no such growth curves exist in Chile. As they are based on the U.S. population, the 2000 CDC curves may not be appropriate for the Chilean population given the largely genetic component of height and weight (273), unless the research goal is a U.S.-Chile comparison, which in this analysis, is not necessarily the case.

To that end, a third option is to develop within-sample percentiles so that the reference population is Chilean. The 85th through 95th percentile would be defined as overweight, and 95th and above would be obese. The biggest limitation with this approach is that the obesity prevalence is the complement of the percentile chosen. If the within-country BMI distribution is right skewed, which many contemporary populations are, obesity prevalence would be underestimated (274). Further, based in a Chilean population, inter-country comparisons would be difficult. Another limitation of any percentile-based approach, including the 2000 CDC curves, is that the selection of the percentiles are essentially arbitrary and tend to be biased towards numbers that end in five, as Flegal points out (258).

The fourth possibility is to implement ALPHA's (116) recommendations, which are cut-points adapted from percentiles from the Spanish AVENA study (264). These curves, like the 2000 CDC curves, are not appropriate because they are based on a unique population. Further, they are also not criterion-referenced.

The fifth option is to utilize the WHO 2007 standards (260), which align closely with the previously developed WHO under-five curves (260). Unlike the IOTF standards, the WHO 2007 standards are derived solely from a U.S.-based sample. They therefore present concerns with regards to global universality, in spite of the 1995 WHO endorsement of part of the sample for global use (275). An evaluation of the feasibility of international growth standards for school-aged children and adolescents (276) prior to the 2007 release of the WHO child and adolescent growth curves recognized this universality limitation. The 2007 WHO curves share two other limitations with 2000 CDC and IOTF. First, the sample is right-skewed, resulting in an underestimation of obesity prevalence in certain age groups (276). Secondly, the WHO standards, like all previously mentioned, were not explicitly developed to predict health outcomes. Nevertheless, like the IOTF cut-points, since their development, they have been shown to identify children with higher metabolic and vascular risk (277). On a more subjective criterion, the WHO 2007 cut-points were recently utilized by Chilean childhood obesity experts (202), an indication the curves may be appropriate for the Chilean young population.

The only prospectively criterion-referenced BMI cut-points to define obesity in youth to date are the 2011 cut points developed by the FITNESSGRAM group (262). The FITNESSGRAM standards were validated using receiver operating curves based on metabolic-syndrome-linked percent body fat (262) from a sample of 5-18 year olds from NHANES 1999-2004 (262).

Three finalists emerge from the discussion of how to classify BMI-defined obesity in Chilean adolescents: FITNESSGRAM 2011 (262), WHO 2007 (260), and IOTF (261). FITNESSGRAM 2011 (262) stands out as the only set of cut points developed with health outcomes in mind, though the other two have been since validated with respect to cardio-metabolic risk (268, 277). However, FITNESSGRAM 2011's drawback is that it was developed in a U.S.-specific population, a drawback it shares with WHO 2007. All three choices are defensible, but the most important decision criterion for the goal of this study is that the cut-points be criterion-referenced. Therefore, we will use the 2011 FITNESSGRAM BMI cut-points for analytical purposes, but will also present WHO 2007 and the IOTF cut-points in descriptive tables for comparison purposes, per the International Journal of Pediatric Obesity's policy recommendation (274). The 2011 FITNESSGRAM cut-points, like those for CRF, classify BMI into three groups: "healthy fitness zone," "needs improvement" and "needs improvement – health risk."

Waist Circumference Classification

Similar to BMI, there is little agreement as to how to classify waist circumference in adolescents. Two classification approaches are possible: percentile based and criterion referenced. Percentiles for adolescent waist circumference exist for several countries, such as the United States (278), Spain (279) (from which the ALPHA cut points (116) are based), Great Britain (5-16.9 year olds (280), 11-16 year-olds (281)), Australia (282), Canada (283), the Netherlands (represented as z-score) (284), Turkey (285), Italy (286), Cyprus (287), Germany (288), Malaysia (289), Bulgaria(290), Poland (291), Finland (292), Hong Kong (293), Portugal (294), Japan(295), Cuba(296), Iran (297), and China (Hong Kong) (293). No waist circumference percentiles have been developed in Chilean adolescents. As with the BMI statistically developed curves, utilizing percentile-based waist circumference curves to assess health risk is not ideal. While acknowledging the limitations of a percentile-based approach, the International Diabetes Federation (IDF) recommends utilizing the sample-specific 90th percentile (or the adult cutpoint if lower) for classifying high waist circumference in children 10-16 years old as a component of their definition of the metabolic syndrome (207). For individuals 16 years and older, the IDF cutpoint is 94 cm for Europid males and 80 cm for Europid females (207). In addition to the lack of basis in disease risk, another limitation to the IDF-endorsed, sample-specific approach is that which was previously mentioned for BMI: modern populations have right-skewed weight distributions (274), so assigning 10% of the population with high waist circumference is likely to be an underestimation of abdominal obesity. As a result of these two limitations, the IDF recommendations were not employed.

The second approach, as with BMI, is criterion-referenced waist circumference cut-points, which have been created in adolescent samples from the U.S. (Bogalusa Heart Study (118), NHANES III (1988-1994) (298), and NHANES 1999-2004 (299)), Brazil (300), New Zealand

(301), and China (302, 303). Criterion-referenced waist circumference cut-points have been created for Chilean adults (208, 209, 304), but not among youth. Two issues emerge when deciding which of the risk-based cut-points are most appropriate for the Chilean 8th grade population. First, the cut-points vary considerably (Table 5). Second, waist circumference may naturally vary across nationality and ethnicity, an issue cited by the IDF as a reason for the recommended sample-specific percentile approach (207).

As with BMI, the positive aspects of a criterion-referenced cutpoint—that they can be directly linked to disease risk—outweigh the downside of the potential lack of inter-country generalizability. Considering all criterion-referenced cut-points presented in Table 5, we used the 2008 cut-points derived from the U.S. NHANES 1999-2004 data (299) because of its large sample size, its age-specific cut-points (compared with, for example, the 2011 analysis of NHANES III data (298) or the Brazil values (300), which provide single values for all of adolescence), and relatively generalizable ethnicity (compared with, for example, the Bogalusa, Louisiana Study (118)).

The ethnicity component requires further explanation. The selected cut-points (299) provide three different sets of cut-points: one for non-Hispanic whites, Hispanic whites, and non-hispanic blacks. Race is not provided in the SIMCE 2011 data, but Chile is roughly 59% white, 5-8% indigenous, and about 25% "mestizo" (of mixed European and indigenous descent) (305, 306). The Hispanic category was created in the 1999-2004 NHANES data by combining the two categories of Mexican American and other Hispanic (299). In descending order, Hispanics in the United States originate from Mexico, Puerto Rico, Cuba, and Central America (307). Just 3.8% of Hispanics in the United States are of South American origin and within that demographic, only 0.2% identify as Chilean (307). The Hispanic category thus seems to be a poor fit for the Chilean population. Although the non-hispanic white category does not ideally reflect the Chilean distribution of ethnicity, it is likely the best fit of the options available.

Table 5. A selection of adolescent waist circumference classification cut-points criterion referenced by clustered cardiometabolic risk factors

Sample Title	Sample country	Age group, years[a]	Ethnicities included	Year of study	Citation
NHANES III 1988-1994	USA	12 -19 grouped together	none specified	2011	(298)
Bogalusa Heart Study	USA (LA State)	13,14,..,18	Non-hispanic white; Non-hispanic black	2004	(118)
NHANES 1999-2004	USA	13,14,..,19	Non-hispanic white; Non-hispanic black; Hispanic white	2008	(299)
319 children from Sao Paulo	Brazil	10 -19 grouped together	none specified	2011	(300)
580 children	New Zealand[b]	13,14,..,18	none specified	2001	(301)
9 Chinese studies, n=65,898	China	13,14,..,18	none specified	2010	(302)

[a]Most thresholds calculated with whole ages at the mid-year.

[b]Criterion referenced from trunk fat mass

Sociodemographic variables classification

The methodology SIMCE used to define socioeconomic status is available here (308). Briefly, socioeconomic status was categorized by the Ministry of Education into five groups based on household educational attainment and income.

School type was defined as public, private, or subsidized.

With respect to urbanicity, the Chilean National Institute of Statistics (INE by the Spanish acronym) defines a location as urban if it fulfills any of the following criteria:

- If there are more than 2,000 inhabitants or
- If there are between 1,001 and 2,000 inhabitants with at least half the population working in secondary (industry, manufacturing) or tertiary (services, transportation, sales) economic activities or
- If there more than 250 households and the primary function of the area is tourism and recreation.

Berdegué et al.(216), among others (217-219), have argued that this definition grossly underestimates the size of the rural sector. Therefore, we used the urban-rural definition proposed by Berdegué et al.(216). This definition is convenient analytically because each comuna is defined as either rural or urban, so potential rural-urban differences within comuna were not considered. Its convenience is its limitation: this method does not capture within-comuna differences in rurality.

Statistical Analysis

All variables were checked for normality of distribution before analysis using histograms and Q-Q plots. None required transformation. To investigate potential for selection bias, we compared students with missing values for 20mSRT, standing broad jump, and urban versus rural to students with valid values for these three variables in the working sample of 19,904. These three variables had a substantial proportion of missing values (Figure 1). For each of the three variables, we calculated the relative risk of a missing value by sociodemographic and other fitness variables. This analysis was gender stratified for CRF and urban versus rural, but not in SBJ due to small sample size of missing values. To assess significance, we used chi-square and Mantel Haenszel test for trend when greater than two categories.

Analysis of the three variables with a high number of missing values—cardiorespiratory fitness, standing broad jump, and urban versus rural—in the working sample of 19,904 students revealed several significant differences (all $p<0.001$; Table 10, appendix) across groups within and without missing data. The 1,976 students with missing CRF data were about 3 times more likely to be female. In general, both genders with missing cardiorespiratory fitness values were more likely to be less fit in the other three fitness categories, with boys having larger effect sizes. The 127 students with missing MSF values were more likely to be older, attend a public school, and live in an urban *comuna*. The 2,643 students for whom the urban-rural classification (216) was not possible were significantly different from their counterparts in the 4 fitness variables in boys and in school type in girls.

For descriptive purposes, age was categorized in one-year groups; 16-18 year olds were collapsed into one group due to small sample in that age group. Chi-square was used to assess gender differences for dichotomous demographic variables. For demographic variables with more than two categories, including WHO 2007-classified and IOTF-classified BMI, a two-sided one-sample binomial test was used to test difference in gender proportion within category. The null hypothesis for these one-sample binomial tests was that the proportion of females within a given stratum was equal to the overall sample proportion of females. T-tests were used to compare fitness variable means across gender. Chi-square was used to compare fitness variable frequencies across gender. In addition to assessing the prevalence of the high risk group of each fitness variable individually by gender, we investigated prevalence of combinations of aggregate low fitness (e.g. prevalence of needs improvement – high risk CRF combined with low MSF).

Subsequently, we stratified the high-risk group of each of the four fitness variables by each of the demographic variables and each of the other 3 fitness variables. When either CRF or BMI were the outcome of interest in stratified analysis, we dichotomized by collapsing the "needs improvement" and "healthy fitness zone" categories. If not acting as the outcome of interest, BMI and CRF were left in three categories.

Finally, we fit four multivariate log binomial regression models to obtain the adjusted relative prevalence of the high risk category of each fitness variable of interest—CRF, MSF, BMI, and WC—by status of demographic variables and the other fitness variables. Log binomial regression was preferred to binomial logistic regression due to the high prevalence of the risk group in each fitness variable (309, 310). In each of the 4 models, all independent variables were interacted with gender, creating, in effect, 4 gender-stratified models. Multicollinearity was diagnosed using variance decomposition proportions (VDP) and condition indices (CNI). Collinearity was determined if the largest CNI exceeded 30 and two of its corresponding VDPs were as large or larger than 0.5 (311).

School type and SES were highly collinear in each model, so we removed school type from all four models. When CRF and BMI were the response variables of interest, we dichotomized by collapsing “needs improvement” and “healthy fitness zone” categories. When acting as independent variables, CRF and BMI were kept in three categories. In the multivariate models, age was grouped into two categories using 15 years as the cutpoint. Region was also dichotomized into Santiago Metropolitan region and the other 14 regions. Similarly, SES was dichotomized into the high versus the bottom four groups. The remaining demographic variable in each model was urban versus rural. The final four models in mathematical notation are shown in the subsequent section. All analyses were done in SAS 9.3 (Cary, NC). P-values less than 0.05 and prevalence ratios whose 95% confidence interval excluded 1 were considered statistically significant.

Log Binomial Regression Models

Model 1 – Cardiorespiratory fitness

$$Pr(CRF2 = 1|WC, MSF \ldots MALE * STGO) = EXP(\alpha + \beta_1 * WC + \beta_2 * BMI3 + \beta_3 * MSF + \beta_4 * AGE + \beta_5 * SES + \beta_6 * URBAN + \beta_7 * STGO + \beta_8 * MALE + MALE * (\sigma_1 * WC + \sigma_2 * MSF + \sigma_3 * AGE + \sigma_4 * SES + \sigma_5 * URBAN + \sigma_6 * STGO))$$

Model 2 – Musculoskeletal fitness

$$Pr(MSF = 1|WC, BMI3 \ldots MALE * STGO) = EXP(\alpha + \beta_1 * WC + \beta_2 * BMI3 + \beta_3 * CRF3 + \beta_4 * AGE + \beta_5 * SES + \beta_6 * URBAN + \beta_7 * STGO + \beta_8 * MALE + MALE * (\sigma_1 * WC + \sigma_2 * BMI3 + \sigma_3 * CRF3 + \sigma_4 * AGE + \sigma_5 * SES + \sigma_6 * URBAN + \sigma_7 * STGO))$$

Model 3 – Body Mass Index

$$Pr(BMI2 = 1|WC, MSF \ldots MALE * STGO) = EXP(\alpha + \beta_1 * WC + \beta_2 * MSF + \beta_3 * CRF3 + \beta_4 * AGE + \beta_5 * SES + \beta_6 * URBAN + \beta_7 * STGO + \beta_8 * MALE + MALE * (\sigma_1 * WC + \sigma_2 * MSF + \sigma_3 * AGE + \sigma_4 * SES + \sigma_5 * URBAN + \sigma_6 * STGO))$$

Model 4 – Waist Circumference

$$Pr(WC = 1|MSF, BMI3 \ldots MALE * STGO) = EXP(\alpha + \beta_1 MSF + \beta_2 * BMI3 + \beta_3 * CRF3 + \beta_4 * AGE + \beta_5 * SES + \beta_6 * URBAN + \beta_7 * STGO + \beta_8 * MALE + MALE * (\sigma_1 * MSF + \sigma_2 * BMI3 + \sigma_3 * CRF2 + \sigma_4 * AGE + \sigma_5 * SES + \sigma_6 * URBAN + \sigma_7 * STGO))$$

where WC = dichotomous waist circumference

MSF = dichotomous musculoskeletal fitness

BMI2 = dichotomous body mass index (ref = collapsed healthy + needs improvement)

BMI3 indicates two body mass index dummy variables (ref = healthy)

CRF2 = dichotomous cardiorespiratory fitness (ref = collapsed healthy + needs improvement)

CRF3 indicates two dummy variables for cardiorespiratory fitness (ref = healthy)

MALE = gender (ref = female)

AGE = dichotomous age with 15.0 years as cutpoint

SES = dichotomous socioeconomic status (lower 4 groups; ref = highest)

URBAN = dichotomous urban (ref=rural)

STGO =dichotomous region (Santiago Metropolitan; ref = other 14 regions)

RESULTS

Descriptive statistics

The descriptive characteristics of the Chilean 8th grade students are presented in Table 6. Roughly half of the students were 14 years old. Proportionately more boys were in the older age groups than girls (p<0.001). About a third of students each were low-middle SES and middle SES. For school type, almost half of students attended subsidized schools and almost half attended public schools, while fewer than 10% attended private schools. With respect to geographical place of residence, about two thirds of the students lived in urban *comunas*, while one third lived in the Santiago Metropolitan region. The WHO 2007 cut-points (312) classified a proportionately higher overweight prevalence in girls (p<0.001) but higher obesity prevalence in boys (p=0.02). The IOTF cut-points (261) classified fewer students as overweight and obese than the WHO 2007 cut-points.

Table 7 presents univariate descriptions of the health-related fitness in the sample by gender. In general, health-related fitness was lower in girls. Girls had twice the prevalence of needs improvement – health risk CRF (31%) as boys (15%) (p<0.001), a higher prevalence of low MSF (p<0.001), and a higher prevalence of needs improvement – health risk BMI (p<0.001). In contrast, prevalence of high waist circumference did not differ significantly by gender. Combined fitness levels were, accordingly, lower in girls in 8 of the 9 combinations examined (p<0.001 if difference).

Bivariate associations

Tables 8.1 through 8.4 present bivariate unadjusted associations for each of the 4 fitness characteristics by demographic characteristics and the other fitness components. In increasing numerical order for the four tables (8.1-8.4), the outcomes are needs improvement – health risk CRF, low MSF, needs improvement – health risk BMI, and high WC. Almost all the fitness variables differed significantly across age group, socioeconomic status, and school type. Overall, the proportion of low cardiorespiratory (Table 8.1) and musculoskeletal fitness (Table 8.2) increased with age (p for trend <0.001), while the proportion of low body mass index (Table 8.3) and waist circumference (Table 8.4) either decreased (p for trend <0.001) or did not differ significantly with age. For all four fitness variables, students with higher SES had better fitness than students of lower SES groups (all p for trend <0.001). Of note, a stark drop in prevalence of low fitness was observed in the highest of the five SES groups. Students attending private schools had better fitness than counterparts at subsidized or public schools across all four fitness variables (all p for trend <0.001).

Compared with age, SES, and school type, fitness differed in relatively fewer comparisons across geographical place of residence (both urban versus rural and Santiago Metropolitan versus the remaining regions). In girls, prevalence of needs improvement – health risk CRF was higher in urban areas, but prevalence of needs improvement – health risk BMI and high WC were higher in rural areas (all $p \leq 0.001$) (Table 8.1, 8.3, 8.4), while prevalence of MSF did not differ by urban versus rural place of residence (Table 8.2). No fitness component differed in boys across urban versus rural location (Tables 8.1-8.4). Five of the eight gender-fitness combinations demonstrated significant variation in prevalence of low fitness between Santiago Metropolitan and the rest of the country. In general, the prevalence of at risk body composition (i.e. needs improvement – health risk BMI and high WC) was higher outside of the Santiago region, whereas the prevalence of low fitness indicated by CRF and MSF was higher in Santiago (if significant $p \leq 0.006$).

The risk categories of all four fitness characteristics were all strongly associated with each other in all combinations. Over a third of males and almost half of females with needs improvement – health risk BMI also had needs improvement cardiorespiratory fitness (p for trend < 0.001; Table 8.1). Needs improvement health risk CRF was also associated with high WC and low MSF (p for trend < 0.001; Table 8.1, 8.2, 8.4). Furthermore, low MSF was associated with high WC and needs improvement – health risk BMI (p for trend < 0.001; Table 8.2, 8.3, 8.4). Finally, the two risk groups of the two body composition characteristics, BMI and WC, were strongly associated (p for trend < 0.001; Table 8.3, 8.4).

Multivariate models

The association between health-related fitness characteristics

To identify independent associations between the fitness variables and sociodemographic variables, we fit four multivariate log binomial regression models (Tables 9.1 through 9.4). In each model, one of the four fitness characteristics acted as the outcome variable while the remaining fitness and demographic characteristics acted as predictors. Similar to the unadjusted bivariate pattern, almost all of the 4 fitness variables showed strong adjusted associations (prevalence ratio > 1) with each other, many of which significantly varied by gender.

For the CRF model (Table 9.1), independent of WC, MSF, and sociodemographic variables, the prevalence of needs improvement – health risk CRF was almost twice as high among students with needs improvement – health risk BMI compared with healthy BMI counterparts (p < 0.001). On the contrary, males with needs improvement BMI did not have different CRF compared to their healthy BMI counterparts, but needs improvement – health risk CRF was 1.3 times more prevalent in females with needs improvement BMI (p < 0.001). Prevalence of needs improvement – health risk CRF was also significantly higher among students with high waist circumference ($p \leq 0.003$) and students with low musculoskeletal fitness ($p<0.001$). In each case, the effect size was significantly higher in boys (p, gender interaction <0.001).

For the MSF model (Table 9.2), similar to the CRF model, the prevalence of low MSF was higher among students with needs improvement – health risk BMI compared with healthy BMI counterparts, independent of WC, CRF, and sociodemographic characteristics ($p < 0.001$). The effect size was higher in males (p, gender interaction <0.001). In contrast with the CRF model, students with high waist circumference did not, after adjustment, have significantly different musculoskeletal fitness compared with students with normal waist circumference counterparts. Finally, prevalence of low musculoskeletal fitness was significantly higher among students of each CRF risk group ($p < 0.001$). Notably, the effect size of the CRF needs improvement - health risk group was about 1.3 times the effect size of the CRF needs improvement group.

For the BMI model (Table 9.3), needs improvement – health risk BMI was about eight times as prevalent in girls with high waist circumference compared to girls with normal waist circumference, after adjustment ($p<0.001$). The effect size was twice as high in males ($p<0.001$; p, gender interaction <0.001). The risk groups of MSF and CRF were also more likely to have needs improvement – health risk body mass index than their normal counterparts ($p \leq 0.002$).

Lastly, for the WC model (Table 9.4), the relative prevalence of high WC among students with NI – health risk BMI compared to healthy BMI ($p<0.001$) was twice as large as the relative prevalence of high WC among students with needs improvement BMI ($p<0.001$). Like in Table 9.2, no association was observed between MSF and WC after adjustment. In contrast to BMI, while each prevalence ratio was significantly above 1 ($p \leq 0.02$), the relative prevalence of high WC among each CRF risk groups was similar to one another.

In summary, the four fitness variables were strongly correlated with each other in this sample, and in many cases, the strength of the association was higher in males.

The association between health-related fitness and demographic characteristics

Similar to the unadjusted results, students' fitness levels, more often than not, significantly varied by age group and socioeconomic group, but differed less by geographic location (Tables 9.1-9.4). For both cardiorespiratory and musculoskeletal fitness, older students were more likely to be unfit than their younger counterparts ($p \leq 0.04$; Tables 9.1, 9.2). On the other hand, the two adiposity fitness components did not differ across age group, with the exception of age and BMI in males. Needs improvement – health risk BMI in males was, contrary to CRF and MSF, less prevalent among the older age group ($p<0.01$; Table 9.3).

For the most part, the association between socioeconomic status and the fitness variables was less pronounced in the adjusted models (Tables 9.1-9.4) compared to the bivariate associations (Tables 8.1-8.4). Still, in all but one of the eight fitness-gender combinations, students in the lower four socioeconomic groups were more likely to be unfit compared to their high socioeconomic status counterparts ($p \leq 0.03$). This association was strongest for musculoskeletal fitness (PR=2.09 for boys and PR=2.71 for girls). As the exception, socioeconomic status did not differ by waist circumference status in males.

The demographic characteristics *urbanicity* and *Santiago region* were not redundant (Table 6). Accordingly, the associations of urbanicity and the Santiago Metropolitan area with fitness variables were not identical. Fitness variables did not differ by urban or rural status except for three of the eight fitness-gender combinations. The adjusted prevalence of needs improvement – health risk CRF was significantly greater in urban areas than in rural areas ($p<0.01$; Table 9.1). In contrast, urban females were less likely to have high waist circumference than their rural counterparts ($p<0.001$; Table 9.4). The adjusted prevalence of low fitness, similarly, did not differ much between the Santiago Metropolitan area and the rest of the country. Female low musculoskeletal fitness prevalence was higher in Santiago compared with the rest of the country ($p<0.001$), but high waist circumference prevalence was higher in regions outside of Santiago compared with Santiago ($p<0.04$). In conclusion, low fitness prevalence varied by age group and was lower in students of high socioeconomic status, but varied less across geographical location.

DISCUSSION

The overall goal of this study was to describe the health-related physical fitness, including cardiorespiratory fitness, musculoskeletal fitness, and body composition, of a large, population-based sample of Chilean 8th graders in 2011. Additionally, we aimed to identify significant correlates of low cardiorespiratory fitness, musculoskeletal fitness, and excessive adiposity, after adjusting for potential confounders in the sample of Chilean 8th graders. We found, in general, a high prevalence of low fitness in Chilean 8th graders, especially in girls. The components of low physical fitness were all strongly associated with each other and with many demographic characteristics.

Contextualization of health-related fitness

Contextualization of prevalence of low cardiorespiratory fitness

For cardiorespiratory fitness (CRF), about 1 in 4 boys and over half of girls failed to meet the 2011 FITNESSGRAM (250) healthy standards (Table 7). In contrast, in the field evaluation of the 2011 FITNESSGRAM standards (313), the same proportion of Midwestern U.S. adolescent boys (25%) and a smaller proportion of girls (23%) failed to achieve the shuttle-run-assessed healthy fitness zone.

Few studies (314-317) apart from the field evaluation (313) have implemented the 2011 FITNESGRAM standards (250), making further comparison using these standards difficult. Many have used the validated (251) 2004 FITNESSGRAM standards (318). Under the 2004 FITNESSGRAM standards (318), 23% of boys and 25% of girls had unhealthy CRF in the present Chilean 8th grade sample (Table 11; appendix). In effect, the 2011 standards split the 2004 unhealthy group in two for boys and divided the 2004 healthy group in two for girls (313).

The proportion with unhealthy CRF by the 2004 standards is relatively consistent with estimates of adolescent CRF from other developed countries. More Chilean 8th graders had unhealthy CRF than adolescents in Sweden (9% of boys and 20% of girls) (90) and Spain (19% of boys and 17% of girls) (319), but roughly the same proportion had unhealthy CRF as adolescents from Australia (29% of boys and 23% of girls) (320). In contrast, a smaller proportion of Chilean 8th graders had unhealthy CRF compared with adolescents across Europe (39% of boys 43% of girls) (253) and U.S. 12-15 year-olds (~30% in both genders) (251).

Limitations in the literature prevent meaningful temporal and regional (i.e. South American) comparison. European and U.S. youth CRF levels are thought to have declined in recent decades (321-325), though infrequent and methodologically variable fitness surveillance instills little confidence in generalizable trend estimation (8, 326). Still, under the assumption that CRF has, in fact, declined in other parts of the world, the observed prevalence of low CRF is similar to or higher than the worst adolescent CRF that has ever been recorded elsewhere, outside of Sweden and Spain.

The only comparable study in another South American country occurred in a school in Bogota, Colombia, in which the 13-15 year-old students were considerably less fit (almost two thirds were unhealthy by the 2004 FITNESSGRAM standards (318)) than the present study's 8th graders (230). Presenting a within-country comparison opportunity, cardiorespiratory fitness was measured in 9th graders in a low-income neighborhood of South Santiago, Chile (221). The study did not assess the proportion with unhealthy 2004 FITNESSGRAM-classified CRF, but observed an overall baseline mean maximal aerobic capacity (VO2max) of 36 ml/kg/min, which is considerably lower than the population-based 8th grade mean VO2max observed in the present study (40 ml/kg/min in boys and 35 ml/kg/min in girls). This difference could be explained by the neighborhood's low average income level or methodological differences in assessing VO2max.

The present study will allow for further temporal and regional comparison of adolescent cardiorespiratory fitness.

Potential classification and internal selection bias in cardiorespiratory fitness estimation

An important consideration throughout the contextualization of the sample of Chilean 8th grade CRF with other studies is the potential for classification and internal selection bias. *Internal* in this case refers to the students who were tested on other fitness indicators, but excluded from the cardiorespiratory fitness assessment.

Presenting potential for classification bias, the aforementioned studies measured VO2max using different methods. CRF estimates from the U.S. (251) and Sweden (90) were obtained using lab-based VO2max estimation methods (327, 328). The remaining compared studies (230, 253, 319, 320) estimated VO2max from performance in the field-based 20m shuttle run test (20mSRT) (235) (except for the Santiago study (221), which used a separate field-based method (329)). One of many potential equations was then employed to estimate VO2max based on performance in the 20mSRT. The studies from Australia, (320), Spain (320), and Bogota, Colombia (230) estimated VO2max from the 20mSRT with the equation used in the present study (235), while estimates from across Europe (253) and from the 2011 FITNESSGRAM field evaluation (313) were each obtained using a different 20mSRT equation (245, 313).

All other things equal, comparison with Australia (320), Spain (320), and the school in Bogota, Colombia (230) is thus the most valid. The Leger equation (235) used in the present investigation underestimates VO2max relative to the lab-based estimation method and the other 20mSRT equations (244) (245, 249). Therefore, considering this potential misclassification alone, fewer Chilean 8th graders likely had poor 2004-FITNESSGRAM(318)-classified low CRF than the comparison with the U.S. (251), Sweden (90), Europe (253), and the Midwestern U.S. field test sample (313) suggests.

Another potential methodological misclassification may bias the true proportion achieving healthy CRF downward. In the present study, VO2max was estimated based on the last one-minute stage completed in the 20mSRT. This method may result in an underestimation of VO2max because participants stopping just short of completing the marginal stage would be ascribed to the previously completed stage. To alleviate this issue, Ruiz et al. suggest recording half stages (245), an implemented recommendation in the Europe-wide estimates (253), but half stages were not available in the SIMCE data.

Two sources of potential misclassification may have biased the VO2max estimate downward, but internal selection bias likely drove the VO2max estimate upward, winning the bias “tug of war.” In the working sample of students, 10% had missing cardiorespiratory fitness data (Figure 1), in large part because they were deemed ineligible following the cafra test (229). Students excluded were more likely to be female and have low MSF, needs improvement – health risk BMI, and high WC (Table 10; appendix). Given the high correlation we observed between the risk groups of all fitness variables (Tables 8.1-8.4, 9.1-9.4), the students without CRF data in the working sample almost certainly had lower mean VO2max than those that provided data. Considering the net effect of potential classification and internal selection bias, the reported proportion with unhealthy CRF is likely an overestimation.

Contextualization of prevalence of low musculoskeletal fitness

Estimated with the validated standing broad jump (114), the Chilean 8th grade sample had a high proportion of unhealthy MSF (Table 7). Low MSF was defined by standing broad jump less than the age-and-gender-specific 20th percentile of European adolescents (253). That is, the prevalence of Chilean 8th grade low musculoskeletal fitness was about 1.5 times that of European adolescents (253), who had yet worse MSF than Australian adolescents (320). Musculoskeletal fitness of adolescents in Santiago (221) was assessed using a different method (330) and thus cannot be compared to the present study's results. To the authors' knowledge, MSF has not been evaluated on a national level outside of Europe or Australia, preventing regional comparison and highlighting the importance of the present estimates for improving global fitness surveillance.

Potential for bias in the musculoskeletal fitness estimate is lower than in the CRF estimate. Measurement error is always possible, but we have no reason to believe it was directionally systematic. Likewise, potential for internal selection bias is negligible: the CRF, BMI, and WC of the 1% of students with missing MSF assessment did not differ from the rest of the sample.

Contextualization of prevalence of high body mass index

Like MSF, BMI in the Chilean 8th grade sample was poor by international standards, particularly in girls. In the U.S. sample in which the 2011 FITNESSGRAM BMI cut-points were created, about 10% of both genders had "needs improvement BMI" and another 10% had "needs improvement – health risk" BMI (262). The Chilean 8th grade sample had higher prevalence of both risk groups and, notably, almost triple the U.S. prevalence of the highest risk group in boys (22% versus 8%) and girls (29% versus 10%).

Further comparison, as with CRF, is simpler using more widely-used cut points. The cumulative prevalence of IOTF (261)-classified overweight and obesity in the Chilean 8th graders was about one third. This prevalence exceeds the pre-2006 estimate in school-age children in the Americas, which had the highest cumulative overweight and obesity prevalence of all 6 worldwide regions considered (203). The prevalence of IOTF-classified cumulative overweight and obesity in boys was slightly lower than the 38% of U.S. 12-17-year-old boys in 2003-2004, whereas the U.S. figures are similar in girls (331). The rise in U.S. adolescent overweight and obesity may be leveling off, though it is still increasing slowly in males, as of 2010 (332). The reported comparison for females, then, is likely still appropriate, but the reported male U.S. prevalence may be an underestimation. Contrary to the U.S., in Chile, overweight and obesity prevalence was higher in female 8th graders than males.

Classified by the stricter WHO 2007 cut-points (260), about 4 in 10 of the Chilean 8th graders were either overweight or obese (Table 6), a prevalence similar to Canadian 12-to-17 year-olds in 2004 (37% of boys and 29% of girls) (333), but considerably higher than a sample of Brazilian middle-schoolers in 2006 (20%) (334) and 14-17-year-olds from Spain in 2012 (17%) (335).

Based on previous estimates of Chilean adolescent obesity, the high prevalence of Chilean 8th grade overweight and obesity is not surprising but nonetheless of concern. Defined by the 2000 CDC cut points (200), 15% of male and 18% of female adolescents from multiple cities in Chile in 1998 were obese (Table A) (198), which approximated the U.S. adolescent prevalence in the same time period (201). On the other hand, a 2003 study comparing IOTF (261)-classified cumulative adolescent overweight and obesity prevalence across 6 Latin American cities estimated 19% prevalence in Santiago, which was higher than three of the cities studied but lower than Lima and Panama City (336). Apart from differences in sampling methodology (i.e. potential selection bias), the disparity between 19% and the third that IOTF (261) classified as overweight or obese in the present sample is difficult to explain, even if the present study suggests adolescent male obesity prevalence is lower in Santiago than elsewhere in the country (Table 8.3). Nonetheless, the present study will provide a nationwide basis for future comparison of adolescent overweight and obesity prevalence within Chile and with other countries.

BMI is a reliable test in youth (270), so potential for misclassification is very low. Similarly, BMI was assessed in all students in the working sample, so there is no potential for internal selection bias.

Contextualization of prevalence of high waist circumference

Multiple cut-points were considered to evaluate Chilean 8th grade waist circumference (118, 298-302) (Table E). We chose the cut-points developed by Messiah et al.(299) because they are population-based (albeit not based on the Chilean population), criterion-referenced, and age-specific. These cut points classified 31% with high waist circumference in both genders (Table 7), which is considerably less than the approximate half of the U.S. 1999-2004 NHANES sample, which was classified using the same cut-points (299). Of the four fitness components, waist circumference is most difficult to compare internationally. Acknowledging widely varying cut-points, a 2010 systematic review evaluating worldwide abdominal obesity prevalence (i.e. high waist circumference) (337) concluded that the prevalence of adolescent abdominal obesity ranged from 4% to about 50%. The Chilean prevalence can thus be cautiously placed on the upper end of the global distribution.

WC has been shown to be less reliable than BMI in the school setting (113), so potential for classification bias is higher. In the present study, a representative from the Ministry of Education visited each school to standardize testing methods (338). The anthropometry accuracy could have varied across school, but, based on the reliability study conducted by the ALPHA group in Europe (113), directional systematic error is unlikely. Like BMI, potential for internal selection bias is very low as a negligible number of students had missing WC data.

Explanations for observed low health-related fitness

Considering all four fitness characteristics—except perhaps waist circumference—the prevalence of low fitness in the Chilean 8th graders is lower than or similar to much of existing international data, which is low from a temporal perspective. Additionally, across three of the four fitness measures, again excepting waist circumference, girls had lower fitness than boys, even when using gender-specific cutoffs (Table 7).

There are multiple possible explanations for the low fitness levels observed in the Chilean 8th graders. Possible explanations pertain to the reliability and validity of the tests in the Chilean population, global genetic variation, altitude, and, of course, to true fitness deficiencies in the Chilean adolescent population.

First, the reliability of the tests used to evaluate fitness, including body composition, has not been assessed in the South American school setting. *Reliability* refers to the reproducibility of a test in repeated trials on the same individual in close temporal proximity under the same conditions (234). A European academic group (ALPHA) has demonstrated that all four fitness tests used in the present study are reliable in the school setting, but standing broad jump and waist circumference were the least reliable of the four (113). ALPHA's school-based reliability assessment and the SIMCE assessment could have had varied considerably as a result of, for example, different cultural work expectations, variable prior training physical education teachers and test administrators, and varied interpretation of the administration protocol by the Chilean Ministry of Education representatives. Even if the tests were not reliable in Chile's school setting—a conservative assumption—we have no reason to believe this would systematically bias the fitness levels downward (i.e. it would likely be random error). Moreover, reliability is not expected to differ by gender (113). Reliability concerns are thus an unlikely explanation for the observed low overall fitness levels and disproportionately low female fitness.

A second consideration is the validity of the 20mSRT in the Chilean population. *Validity* refers to the ability of a field-based test to approximate the gold-standard measurement. All four tests used in the present sample have demonstrated validity in adolescents (114). The relevant validity question then becomes whether, in the Chilean school setting, these tests yield a result that can be appropriately compared to other studies which have employed the field tests. The 20mSRT, and, to a lesser extent, the standing broad jump, require intense physical exertion. Compared with other more controlled environments with trained motivational coaches (what might be considered, in other words, the field-test gold standard), in the Chilean school setting, some participants may have been less willing and motivated to endure the discomfort associated with the fitness tests, reasons for which could be personal or sociocultural (e.g. students are embarrassed to sweat or demonstrate effort around their peers). The validity of the 20mSRT and the standing broad jump do not differ by gender (114), but the validity has not been studied in Chile. Chile traditionally has a "machismo" culture (339), which may have contributed to girls exerting less than their maximal effort on the tests in comparison to boys, even by gender-specific standards.

In addition to test-related explanations, another potential explanation is genetic differences between the Chilean population and the nations to which it was compared. Given the substantial genetic contribution to fitness (49, 273), the cut-points used to classify low fitness may have not been appropriate for the Chilean population. Genetic variation and lack of cut-point agreement may help to explain, in particular, the unexpected observation of relatively low prevalence of abdominal obesity (i.e. high WC), but high prevalence of needs improvement – health risk BMI. Due to the poor level of MSF observed (Table 7), one may expect that WC would be relatively worse than BMI, as BMI includes lower-body muscle mass but WC does not. A potential explanation for this apparent discrepancy is international genetic variation and consequent inappropriate cut-points. A future study in this population might include race or ethnicity to improve control for genetic variation.

Another factor that may have affected Chilean 8th grade fitness more so than other countries is altitude. Flanked by the high-altitude Andes to the East and the Chilean Coastal Range to the West, a large proportion of Chile lives in its Central Valley (340). The Central Valley ranges from 1,400 m in elevation in the extreme north, to about 500 m in Santiago, to sea level in the South, near Puerto Montt (341). In individuals not acclimated to altitude, VO2max begins to decline at about 700 m (reviewed in (342)). In children who just relocated from lower elevations to a higher elevation, it is thus plausible that their VO2max could have been underestimated. This potential VO2max underestimation is likely negligible, however, because of the non-VO2-max-altering altitudes of much of population-dense Chile (340, 342) and low expected frequency of household relocation. The potential altitude effect also fails to explain gender differences.

Finally, the observed low prevalence of fitness in Chilean 8th graders could reflect the truth. The reported results are consistent with a growing body of evidence placing Chile at the forefront of the nutritional transition in Latin America (169, 179, 182, 183, 198).

Apart from the commonly cited risk factors of dietary "westernization" and sedentary lifestyle (173), Chile sets itself apart by its world-leading youth smoking prevalence. A startling 34% of 13-15-year-olds—the age of the average 8th grader—in Chile smoke (343), the second highest in the world (343). Among girls this age, 4 in 10 smoke, the highest in the world (343). These world-leading figures help to explain the high prevalence of low cardiorespiratory and musculoskeletal fitness in the Chilean 8th graders, given the adverse effect of smoking on both cardiorespiratory (344, 345) and musculoskeletal (346-348) fitness. Further, that more young girls than boys in Chile smoke helps to explain the higher prevalence of low CRF and MSF in girls compared to boys in the sample. The high adolescent smoking prevalence in Chile may be an indication of a broader attitude towards wellness in Chilean young. Smoking is inversely associated with adolescent team sports participation (349-351) and general physical activity (351), which are protective factors in adolescents for low physical fitness (90, 91, 317), including poor body composition (88). Given smoking's known relation to the primary modifiable determinant of fitness (92), the youth smoking epidemic in Chile likely explains more of the low fitness results than the biological mechanism alone would suggest.

In summary, the observed high prevalence of low fitness in Chilean 8th graders could be partly due to test-related factors, international genetic variation, or altitude. More likely contributors are the common culprits of diet and lifestyle, including smoking.

Adjusted correlates of health-related fitness

The association between health-related fitness characteristics

Cardiorespiratory fitness and body composition

Previous studies investigating the association between fitness and fatness in adolescents suggest that WC is better than BMI at predicting CRF, though both are inferior to more direct measurements of adiposity (103, 107, 352, 353). Our results don't confirm the notion that WC is superior to BMI in discriminating CRF, but do agree that, in general, that both BMI and WC are significant inverse correlates of CRF (Table 9.1,) That this study did not conclude that WC was a stronger correlate than BMI with CRF in adolescents, as others have (103), could be a result of different cut-points used to categorize BMI or WC or a result of international genetic variation.

Regarding gender effect modification, other studies have shown, like ours, that the association between fitness and fatness is stronger in males than females (83, 102).

Apart from the question of which between BMI and WC predict CRF better, this study reinforces the notion that for a given BMI, high WC is associated with low CRF (53, 54, 79, 103, 105). The converse, which has received less attention in the literature (38), is also true in the present analysis: for a given WC, high BMI is associated with low CRF. Both BMI and WC contribute independent information to risk of low CRF and thus NCD disease risk (66).

Although the focus throughout the study has been on students with more than one common health risk factors (e.g. prevalence of needs improvement – health risk CRF among students with needs improvement – health risk BMI), another important group to investigate is the subset of students with needs improvement – health risk BMI yet healthy CRF (i.e. those that are "fat" but "fit."). Among students with needs improvement – health risk BMI, 46% of males and 25% of females had healthy CRF (data not shown). Evidence suggests this subset of students is not necessarily at increased risk for cardio-metabolic disease compared with students with healthy CRF and healthy BMI (21, 354). That is, BMI may not add new information on cardiovascular prognosis independent of CRF (21, 74, 75, 354). It is possible, in other words, to have “healthy” obesity (355). This information on relative disease risk reinforces the conclusion that girls were at greater risk of cardio-metabolic disease than males in the present study.

Musculoskeletal fitness and body composition

Unlike CRF, only BMI category and not WC was independently inversely associated with MSF. Except for the “needs improvement” group in females, needs improvement and NI – higher risk BMI were associated with low musculoskeletal fitness, independent of waist circumference, cardiorespiratory fitness level, and demographic variables (Table 9.2).

Previous studies have shown that adiposity correlates inversely with weight-bearing musculoskeletal fitness assessment (e.g. the standing broad jump) (83, 101, 106, 108-110). Given the generally accepted notion that WC correlates more closely with fat tissue than BMI (255, 356), it is surprising that BMI was more strongly inversely related to musculoskeletal fitness than WC in this sample. Nonetheless, a study sample of Canadian children found the same results, that the effect of WC on MSF is not independent of BMI (106).

Neither BMI nor WC discriminate between lean and adipose body mass (270). However, the mass of the leg muscle, that which is primarily responsible for off-the-ground propulsion in the standing broad jump, cannot be excluded from the BMI calculation, whereas it is inherently excluded from WC. WC, for its part, cannot eliminate abdominal muscle mass, which certainly plays a role in standing broad jump performance. It is possible the 2011 FITNESSGRAM cut-points (262) identified enough excess adiposity—they were developed to discriminate criterion-referenced percent body fat (266) —such that WC added no new information to the fitness versus fatness relationship.

In agreement with our results, previous studies have shown that the association between adiposity and musculoskeletal fitness is higher in males than females (83, 102). One may justifiably hypothesize, however, that the relationship between BMI and MSF would be stronger in girls. As stated, BMI cannot exclude lean mass, and adolescent BMI increases are more often attributable to gains in lean mass in males than females (357, 358). One might thus expect that the larger relative proportion of muscle mass in adolescent males in a given BMI would dilute its negative association with MSF compared with girls. Again, the apparent contradiction could be explained by the discriminating ability of the percent-body-fat-referenced 2011 FITNESSGRAM BMI cut-points (262).

With respect to cardio-metabolic disease risk, evidence suggests low musculoskeletal fitness in youth is a cardiovascular risk factor independent of BMI, WC, and CRF (69). The relative importance of fatness and musculoskeletal fitness has been studied less than the comparison between cardiorespiratory fitness and fatness (21). Nonetheless, the high proportion of students with low musculoskeletal fitness in the present study (Table 7) is concerning for cardiovascular prognosis.

Health-related fitness and demographic characteristics

Age and fitness

The older age group was more likely to have poor CRF and MSF, but slightly less likely to have poor BMI relative to the younger age group in the adjusted models. In contrast, WC did not differ by age.

The observed age-related trends should be interpreted with two considerations in mind. First, differences in fitness by age presented are relative to age-specific cut points. For example, the 2011 FITNESSGRAM CRF cut-points expect CRF to increase with age in boys but to decrease with age in girls (250). In this sample, proportionately more 15-18-year-old boys had high-risk CRF than 13-14 year olds. The expected upward trend in male CRF by age was thus not evident in this sample (in fact, CRF, on an absolute scale, declined with age in boys; data not shown). Similarly, proportionately more 15-18-year-old girls had high-risk CRF than 13-14 year-olds. FITNESSGRAM 2011 expects older girls to be less fit, but the proportion of less fit older girls in this sample exceeded that expectation.

Secondly, the age-related trends observed in this study are notable because the population is restricted to 8th graders. An older 8th grader may differ from his younger counterpart in a systematic manner that includes more than just an earlier birthday. He, for example, could have previously failed a grade. Additionally, the age-related analysis is interesting because their common grade level may help to control for other factors that could confound the relationship between age and fitness, such as social development and, at face value, educational attainment. Grade level would not, however, control for pubertal stage, which would likely confound the association between age and fitness.

It is important to emphasize that—perhaps apart from the 14-year-olds—the prevalence of low fitness observed should not be interpreted as the representative proportion in a given age group. Rather, it should be considered as the prevalence of low fitness in the average Chilean 8th grader. A 17-year-old in the present study of 8th graders, for example, certainly differs from the average Chilean 17-year-old.

Socioeconomic status, school type, and fitness

Low SES is a well-established health risk (359, 360), including in youth (128-130). In this study, we observed that students of higher SES had better fitness, including body composition. Of note, we observed the largest relative fitness increase in the highest of 5 SES groups. It would be less appropriate to state, in other words, that students of low SES had lower fitness. Rather, students of the top SES group consistently had higher fitness than the bottom 4 groups, who, among themselves, had relatively homogenous fitness.

In relative homogeny with these results, evidence suggests that in developing (132) developed countries (131), including Chile (204, 205) (which is upper-middle income (361)), adiposity is inversely related with SES in youth. The association between SES and youth cardiorespiratory and musculoskeletal fitness follows the same general trend (higher SES; higher fitness) (134-136, 362), but the evidence is scarce and inconsistent. In fact, the association between SES and fitness in adolescents has only been assessed once outside of Europe (362). The present study is thus an important contributor to the small and inconsistent body of evidence on this question. Additionally, that the positive association between SES and fitness was independent of other fitness and demographic characteristics is noteworthy, although unmeasured confounding cannot be ruled out.

One potential confounder that we did not control but which showed a significant unadjusted association with fitness was school type. Olds et al. (363) reported that Australian adolescents at private schools had better cardiorespiratory and musculoskeletal fitness than their counterparts at public schools, even after controlling for SES. The former is consistent with our study: Chilean 8th graders attending private schools had better cardiorespiratory fitness, musculoskeletal fitness, BMI, and WC compared with their counterparts at subsidized and public schools (Tables 8.1-8.4). However, we cannot conclude based on our methods whether this association is independent of SES.

Nonetheless, for intervention and policy purposes, the question of independence may not be relevant. In the Chilean sample, the highest SES group and private school type were essentially synonymous. 92% of students in the highest of five SES groups attended a private school; 97% of students in private schools were of the highest SES group (data not shown). The causal pathway between higher SES and higher fitness is likely bidirectional. Students of the highest SES group may, prior to matriculation and throughout their academic career, live in environments which promote health to a greater extent than their counterparts in the other SES groups. That is, private schools may self-select healthier students. Conversely, it is possible that the environment at private schools promotes fitness better than the other two sectors (e.g. through better physical education or team sports opportunities). This demonstrated fitness divide is an important opportunity for intervention. Under the assumption that the private school environment improves fitness, subsidized and public schools could draw lessons from private schools, insofar as budgetary and cultural obstacles permit. Of course, the self-selection causal pathway is more difficult for the other two school types to imitate and would likely require a shift in economic policy outside of this study's scope of recommendations.

Geographical location and fitness

Compared with the fitness differences observed between SES group and school type, the association between geographical place of residence and fitness was small. Evidence suggests that obesity (205) and physical inactivity (186, 211) is higher in rural areas among Chileans at least 15 years of age. In contrast, prevalence of needs improvement – health risk BMI (the FITNESGRAM obesity analogy) did not differ by urban versus rural location. A significantly higher proportion of females, however, had high WC, which is consistent with results from national surveys which show a wider urban-rural obesity gradient among women (205). On the contrary, students from urban areas had a higher prevalence of needs improvement – health risk CRF. Given the relatively established positive association between adolescent physical activity and cardiorespiratory fitness (90, 91, 93), the direction of this association was unexpected, as physical inactivity is apparently higher in rural areas (186, 211).

Globally, variation in youth obesity (142-147, 149-158) and physical fitness (154, 156-158, 160-167) by urban versus rural location is inconsistent or nonexistent. A rough trend of increasing country gross domestic product with higher relative proportion of obesity but lower proportion of low cardiorespiratory fitness in rural compared with urban areas is observable. This trend is perplexing given the association between obesity and low CRF observed in the present study and in other youth populations (79, 103, 105).

Nonetheless, two results of the present study (higher prevalence of high WC in rural girls; higher prevalence of needs improvement – health risk CRF in urban students) were consistent with this expectation. The higher WC in women in rural areas could be explained in part by ethnic differences. The ethnic Mapuche, who represent a greater proportion of rural than urban areas, have shown higher adolescent overweight and obesity prevalence compared with the rest of the Chilean population (364). The higher prevalence of low CRF in urban areas could be explained, in part, by the higher prevalence of smoking in urban areas (134-136, 205, 362). 43% of urban-dwelling individuals over 15 years of age smoke compared with 28% of their rural counterparts (205).

Based on results of the regional distribution of risk factors from national surveys (Santiago was at about the average) (205), the mostly null associations we observed between fitness and the Santiago region versus other parts of the country was expected.

As a whole, the results demonstrate that geographical location is not a substantial risk factor for low fitness, apart from CRF and WC, in Chilean 8th graders. This homogeneity is important from a policy standpoint because it suggests no region (when the choice is Greater

Santiago versus the rest of the country; differences may exist between the individual 15 regions) or population-density category should necessarily merit more priority for an intervention.

Limitations

This study has several limitations, some of which were unavoidable and others which were consciously acknowledged “costs” in analytical decisions. The main limitation is potential selection bias in the prevalence of low fitness. Our analysis suggests that students in the working sample whose cardiorespiratory fitness was not assessed had systematically lower cardiorespiratory fitness (Table 10; Appendix). The reported prevalence of low cardiorespiratory fitness is thus likely an underestimation. Selection bias is also possible between the 28,649 students considered for fitness evaluation and the 19,929 students for whom at least one component of fitness was assessed (Figure 1). This external selection bias likely, if anything, again resulted in an underestimation of low fitness, as students were excluded due to, among other reasons, disability.

Secondly, the sample was a stratified cluster sample, yet we treated it as a convenience sample. Therefore, the results cannot be considered representative of the Chilean 8th grade population. Compared to results which had consider the sample design, the reported prevalence and prevalence ratio point estimates may be different because sample weights were not considered (365). Additionally, the results presented almost certainly had smaller variances compared with those that would have resulted from sampling design adjustment (365). As a result, we may have inappropriately rejected the null hypothesis on several occasions, particularly when the p-value neared 0.05. That is, we may have committed Type 1 errors. A future direction of this analysis will be to appropriately adjust for the complex sampling methodology upon receipt of the necessary information.

Third, the study was cross-sectional, but we did not consider this to be a limitation given our investigative goals. The cross-sectional design does not adversely affect the conclusions that can be drawn from the prevalence of low fitness. It does prevent conclusions of causality in the investigation into the relationships between fitness characteristics and between fitness and demographic characteristics. However, our study objective was not to establish a causal pathway. Rather, we aimed to establish correlates of low fitness to more effectively identify at-risk individuals. The cross-sectional design does not interfere with this goal. The cross-sectional association enables policymakers and interveners to more accurately and efficiently identify individuals at risk of cardio-metabolic events.

Our inferential analysis did have limitations. One is the potential of unmeasured confounding. Notable unmeasured potential confounders in many of the associations we investigated are physical activity, race or ethnicity, and pubertal stage (100, 366).

Another potential limitation in the assessment of the adjusted association between fitness characteristics and each other and demographic characteristics was our decision to categorize all variables in each multivariate model. Had our study objective been to focus on one exposure-disease relationship, controlling for other variables, we would have kept all control variables continuous to maintain their true variation. However, our goal was to interpret the coefficients of every variable in the model as a prevalence ratio, interpretations which would have been more complex using continuous variables. As a result of this decision, some of the adjusted associations we observed may have been slightly inflated compared to the alternative continuous adjustment.

Strengths

In addition to its limitations, this study has several analytical strengths. First, the study assessed prevalence of low fitness using four health-related (66), validated (114), and reliable (113) field tests recommended for youth fitness assessment by a European academic group (ALPHA) (115) and the U.S. Institute of Medicine (8). To interpret these fitness tests, we used age-and-gender-specific, health-related cutoffs (67, 250, 262, 299). A second strength of the study is the interpretability of the multivariate models. To identify significant associations between fitness variables, and between fitness characteristics and demographic characteristics, we used log binomial regression to produce prevalence ratios, which are simpler to interpret than odds ratios, especially with prevalent outcomes of interest (309, 310). A third strength of the study is its large, population-based sample size, allowing the analysis to detect statistically significant associations and trends.

Public health implications

The present study is the first large, population-based study to assess prevalence of low cardiorespiratory fitness and low musculoskeletal fitness in any age group in Latin America. Among the 2011 Chilean 8th grade population-based sample, 6 out 10 boys and 8 out of 10 girls were at increased cardio-metabolic risk according to at least one of the four fitness components assessed (Table 7). Of further concern, between 5% and 10% of the students had a combination of at least three of the four low fitness cardio-metabolic risk factors (Table 7).

This high proportion of unhealthy 8th graders should again draw the attention of Chilean policymakers and educators. The results in the 2011 SIMCE Physical Education government report (229) already attracted their attention. In response to the results, in March of 2012, the Chilean Minister of Education proposed to increase the time spent in physical education in elementary school classrooms around the country (367). This proposed increase in physical education hours was combined with a proposal to modify the curriculum in other grades to promote healthy lifestyles and healthier lunches (367).

Although the Education Minister's policy proposal was nationwide, the present investigation into sociodemographic correlates of low fitness facilitates the identification of a narrower intervention target population. We observed stark differences in fitness by socioeconomic status and school type. If resources are finite, the policy change should place less priority on high SES individuals attending private schools, as they consistently demonstrated higher fitness (Tables 8.1-8.4, 9.1-9.4). We also observed a higher prevalence of low cardiorespiratory fitness in urban areas. Due to the observed association between urbanicity and higher SES (data not shown), prioritizing urban students for increased physical education would contradict the previous recommendation. Instead, a separate intervention should target the smoking epidemic in urban (205) Chilean youth (343), given the link between smoking and cardiorespiratory fitness (134-136, 205, 362). Country-specific research is needed to evaluate the effectiveness of such a proposal. Nonetheless, after the 2013 law banning smoking in indoor public places, the public policy framework for such an intervention is strong (368).

In addition to identifying intervention opportunities, the present study provides an evidence-based portrayal of future disease burden—in the absence of a change in trajectory. Each fitness component assessed was chosen (8, 66, 115) and classified (67, 250, 262, 299) according to its contribution to future cardio-metabolic disease risk. The results thus more confidently discriminate students of high risk compared to the previous 2011 SIMCE Physical Education report (229).

Lastly, the study has global significance, as it incrementally improves the inadequate worldwide physical fitness surveillance. The American Heart Association explicitly underscored the need for a national U.S. cardiorespiratory fitness registry (27). Because Chile (198) and many other developed and developing countries alike share characteristics of the U.S.'s NCD-related epidemiologic profile (59, 123), the AHA recommendation can justifiably be extrapolated as a global call for improved fitness surveillance. This study helps to fulfill that global need.

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TABLES

Table 6. Demographic characteristics, including body mass index, of a population-based sample (N = 19,904)[a] of Chilean 8th grade students: The 2011 National Education Survey (SIMCE)[b]

	Males (n = 10,309)		Females (n = 9,595)		
Characteristic	%	n	%	n	p[#]
Total	51.8%	10,309	48.2%	9,595	<0.001
Age (year)					
13-13.9	36.6%	3,775	42.6%	4,089	<0.001
14-14.9	49.3%	5,086	48.9%	4,696	0.69
15-15.9	10.4%	1,072	6.5%	626	<0.001
16-17.9	3.6%	376	1.9%	184	<0.001
Socioeconomic status[c]					
Low	12.5%	1,278	11.5%	1,100	0.06
Low-middle	31.9%	3,276	32.2%	3,081	0.69
Middle	33.8%	3,469	34.2%	3,271	0.61
Middle-high	12.6%	1,293	14.7%	1,406	<0.001
High	9.2%	942	7.4%	705	<0.001
School Type					
Private	8.6%	888	6.4%	612	<0.001
Subsidized	46.0%	4,743	48.2%	4,623	0.03
Public	45.4%	4,678	45.4%	4,360	0.96
Urbanicity[d]					
Rural	36.4%	3,265	38.2%	3,172	0.01
Urban	63.6%	5,710	61.8%	5,122	
Region					
Santiago Metropolitan	36.2%	3,736	33.6%	3,221	<0.001
All other regions	63.8%	6,573	66.4%	6,374	
Body mass index (WHO 2007)[e]					
Normal	61.1%	6,299	57.8%	5,550	0.003
Overweight	26.0%	2,678	30.5%	2,922	<0.001
Obese	12.9%	1,332	11.7%	1,123	0.02
Body mass index (IOTF)[f]					
Normal	68.2%	7,026	63.9%	6,135	<0.001
Overweight	24.2%	2,497	28.5%	2,736	<0.001
Obese	7.6%	786	7.5%	724	0.86

[a]Working sample excludes individuals 18 years and older and with missing BMI. Sample sizes vary slightly by demographic variable.
[b]SIMCE (Sistema de Medición de la Calidad de la Enseñanza; System for Measuring the Quality of Education) 2011 (229)
[c]Groups defined by Chilean Ministry of Education (308)
[d]Berdegue et al. (216); n, urbanicity = 17,269
[e]WHO 2007 BMI-for-age cutpoints (260)
[f]International Obesity Task Force cutpoints (261)
[#]P-values reflect gender differences within strata

Table 7. Criterion-referenced health-related fitness[†] in a population-based sample (N = 19,904)[a] of Chilean 8th grade students: The 2011 National Education Survey (SIMCE)[b]

Fitness Characteristic[‡]	Males (n = 10,309)		Females (n = 9,595)		p[#]
Cardiorespiratory fitness (mL/kg/min)[c,d]	46.4	(6.4)	39.1	(5.2)	<0.001
Healthy		74.2%		44.5%	
Needs Improvement		10.8%		24.8%	<0.001
NI - Health Risk		15.0%		30.7%	
Musculoskeletal fitness (cm)[e]	169.4	(28.1)	131.2	(22.3)	<0.001
Normal		70.8%		65.6%	<0.001
Low		29.2%		34.4%	
Body mass index (kg/m^2)[f]	21.8	(3.8)	22.7	(3.8)	<0.001
Healthy		61.1%		55.7%	
Needs Improvement		17.2%		15.7%	<0.001
NI - Health Risk		21.7%		28.5%	
Waist circumference (cm)[g]	74.3	(9.4)	71.9	(8.8)	<0.001
Normal		69.2%		69.3%	0.88
High		30.8%		30.7%	
Combined fitness					
NIHR CRF & Low MSF		9.2%		16.0%	<0.001
NIHR CRF & NIHR BMI		7.4%		13.3%	<0.001
NIHR CRF & NIHR WC		9.0%		13.5%	<0.001
Low MSF & NIHR BMI		11.5%		14.1%	<0.001
Low MSF & NIHR WC		14.2%		14.1%	0.96
NIHR CRF & Low MSF & NIHR BMI		5.4%		7.9%	<0.001
NIHR CRF & Low MSF & NIHR WC		6.2%		7.8%	<0.001
NIHR CRF & Low MSF & NIHR BMI & NIHR WC		5.1%		6.5%	<0.001
Healthy CRF & Normal MSF & Healthy BMI & Normal WC		39.2%		21.1%	<0.001

[†]Values are mean (SD) or % of category within gender.
[‡]Abbreviations: CRF, cardiorespiratory fitness; NI, needs improvement; MSF, muskuloskeletal fitness; BMI, body mass index; WC, waist circumference; NI, needs improvement; NIHR, needs improvement health risk; VO2max, maximal aerobic capacity; 20mSRT, 20 m shuttle run test
[a]Working sample excludes individuals > 18 years and with missing BMI. Sample sizes vary for each fitness variable: n, CRF= 17,928; n, MSF = 19,777; n, WC = 19,895; n, BMI = 19,904
[b]SIMCE (Sistema de Medición de la Calidad de la Enseñanza; System for Measuring the Quality of Education) 2011 (229)
[c]Cardiorespiratory fitnes is defined by VO2max. VO2max is estimated from 20mSRT using Leger equation (235).
[d]Cardiorespiratory fitness is classified according to FITNESGRAM 2011 VO2max cutpoints (250).
[e]Low musculoskeletal fitness (MSF) is defined as a standing broad jump score <20th percentile of European adolescents (253).
[f]Body mass index is classified according to the FITNESSGRAM 2011 health-related standards (262).
[g]Waist circumference is classified according to health-related cutpoints (299).
[#]Across gender, T-test used to compare means, chi-square used to compare frequencies

Table 8.1.[†] Prevalence (95% CI) of **needs improvement - health risk cardiorespiratory fitness**[h, i] by sociodemographic and other heath-related fitness characteristics in a population-based sample (N = 17,928)[a] of Chilean 8th grade students: The 2011 National Education Survey (SIMCE)[b]

	Males (n = 9,822)			Females (n = 8,106)		
Characteristic	Prevalence	(95% CI)	p, trend	Prevalence	(95% CI)	p, trend
Sociodemographic						
Age (yr)						
13-13.9	12.4%	(11.3%, 13.5%)	<0.001	23.0%	(21.6%, 24.4%)	<0.001
14-14.9	14.9%	(13.9%, 15.9%)		33.1%	(31.6%, 34.6%)	
15-15.9	21.4%	(18.9%, 24.0%)		51.2%	(47.0%, 55.5%)	
16-17.9	23.4%	(19.0%, 27.7%)		68.0%	(60.5%, 75.5%)	
Socioeconomic status[c]						
Low	15.5%	(13.5%, 17.5%)	<0.001	33.0%	(30.0%, 36.0%)	<0.001
Low-middle	15.7%	(14.4%, 16.9%)		34.6%	(32.8%, 36.4%)	
Middle	16.1%	(14.9%, 17.4%)		31.2%	(29.4%, 32.9%)	
Middle-high	14.2%	(12.3%, 16.2%)		27.8%	(25.2%, 30.4%)	
High	8.4%	(6.6%, 10.2%)		14.1%	(11.4%, 16.8%)	
School Type						
Private	8.3%	(6.5%, 10.2%)	<0.001	14.2%	(11.3%, 17.1%)	<0.001
Subsidized	15.1%	(14.1%, 16.2%)		29.9%	(28.4%, 31.3%)	
Public	16.1%	(15.1%, 17.2%)		34.0%	(32.5%, 35.5%)	
Urbanicity[d]						
Rural	13.2%	(12.0%, 14.4%)	0.10	27.4%	(25.7%, 29.1%)	<0.001
Urban	14.5%	(13.5%, 15.4%)		31.9%	(30.4%, 33.3%)	
Region						
Santiago Metropolitan	15.7%	(14.8%, 16.6%)	0.006	30.8%	(29.6%, 32.0%)	0.82
All other regions	13.7%	(12.5%, 14.8%)		30.5%	(28.7%, 32.3%)	
Health-related fitness						
Body Mass Index[e]						
Healthy	8.4%	(7.7%, 9.1%)	<0.001	21.7%	(20.5%, 22.9%)	<0.001
Needs Improvement	13.8%	(12.2%, 15.5%)		31.7%	(29.1%, 34.2%)	
NI - Health Risk	35.8%	(33.7%, 37.9%)		49.4%	(47.3%, 51.6%)	
Waist Circumference[f]						
Normal	8.6%	(8.0%, 9.3%)	<0.001	24.3%	(23.2%, 25.4%)	<0.001
High	30.0%	(28.3%, 31.6%)		46.1%	(44.1%, 48.1%)	
Musculoskeletal fitness[g]						
Normal	8.0%	(7.4%, 8.7%)	<0.001	21.5%	(20.4%, 22.6%)	<0.001
Low	32.5%	(30.8%, 34.3%)		49.4%	(47.5%, 51.3%)	

[†]Abbreviations: CI, confidence interval; NI, needs improvement
[a]Working sample excludes individuals 18 years and older and with missing BMI. Sample sizes vary for each fitness variable: n, CRF= 17,928; n, MSF = 19,777; n, WC = 19,895; n, BMI = 19,904.
[b]SIMCE (Sistema de Medición de la Calidad de la Enseñanza; System for Measuring the Quality of Education) 2011 (229)
[c]Groups defined by Chilean Ministry of Education (308)
[d]Berdegue et al 2010 (216) ; n, urbanicity = 17,269
[e]Body mass index is classified according to the FITNESSGRAM 2011 health-related standards (262).
[f]Waist circumference is classified according to health-related cutpoints (299).
[g]Low musculoskeletal fitness is defined as a standing broad jump score <20th percentile of European adolescents (253).
[h]Cardiorespiratory fitness is classified according to FITNESGRAM 2011 aerobic capacity cutpoints (250).
[i]Aerobic capacity is estimated from 20mSRT using Leger equation (235).

Table 8.2.[†] Prevalence (95% CI) of **low musculoskeletal fitness**[g] by sociodemographic and other heath-related fitness characteristics in a population-based sample (N = 19,777)[a] of Chilean 8th grade students: The 2011 National Education Survey (SIMCE)[b]

	Males (n = 10,240)			Females (n = 9,537)		
Characteristic	Prevalence	(95% CI)	p, trend	Prevalence	(95% CI)	p, trend
Sociodemographic						
Age (yr)						
13-13.9	30.9%	(29.4%, 32.4%)	0.03	35.0%	(33.5%, 36.4%)	0.001
14-14.9	26.2%	(25.0%, 27.4%)		32.3%	(30.9%, 33.6%)	
15-15.9	34.7%	(31.8%, 37.6%)		41.3%	(37.4%, 45.2%)	
16-17.9	40.7%	(35.5%, 45.9%)		57.1%	(49.7%, 64.5%)	
Socioeconomic status[c]						
Low	30.9%	(28.3%, 33.4%)	<0.001	35.1%	(32.3%, 38.0%)	<0.001
Low-middle	31.5%	(29.9%, 33.1%)		39.1%	(37.4%, 40.8%)	
Middle	32.2%	(30.7%, 33.8%)		37.9%	(36.2%, 39.5%)	
Middle-high	25.6%	(23.3%, 28.0%)		27.0%	(24.7%, 29.3%)	
High	13.1%	(10.9%, 15.2%)		11.7%	(9.3%, 14.1%)	
School Type						
Private	13.9%	(11.6%, 16.1%)	<0.001	12.6%	(10.0%, 15.3%)	<0.001
Subsidized	30.4%	(29.1%, 31.7%)		35.3%	(33.9%, 36.7%)	
Public	31.1%	(29.8%, 32.5%)		36.6%	(35.2%, 38.1%)	
Urbanicity[d]						
Rural	28.4%	(26.9%, 30.0%)	0.67	34.5%	(32.8%, 36.1%)	0.98
Urban	28.9%	(27.7%, 30.1%)		34.5%	(33.2%, 35.8%)	
Region						
Santiago Metropolitan	28.3%	(26.8%, 29.7%)	0.08	36.4%	(34.7%, 38.1%)	0.004
All other regions	29.9%	(28.8%, 31.0%)		33.5%	(32.3%, 34.6%)	
Health-related fitness						
Body Mass Index[e]						
Healthy	20.6%	(19.6%, 21.6%)	<0.001	26.8%	(25.6%, 28.0%)	<0.001
Needs Improvement	30.4%	(28.2%, 32.6%)		34.7%	(32.3%, 37.1%)	
NI - Health Risk	53.0%	(51.0%, 55.1%)		49.4%	(47.5%, 51.2%)	
Waist Circumference[f]						
Normal	21.9%	(21.0%, 22.9%)	<0.001	29.3%	(28.2%, 30.4%)	<0.001
High	46.0%	(44.2%, 47.7%)		46.1%	(44.3%, 47.9%)	
Cardiorespiratory fitness[h,i]						
Healthy	19.5%	(18.6%, 20.4%)	<0.001	18.3%	(17.1%, 19.6%)	<0.001
Needs Improvement	42.8%	(39.8%, 45.8%)		33.2%	(31.1%, 35.3%)	
NI - Health Risk	61.5%	(59.0%, 64.0%)		52.4%	(50.5%, 54.4%)	

[†]Abbreviations: CI, confidence interval; NI, needs improvement
[a]Working sample excludes individuals 18 years and older and with missing BMI. Sample sizes vary for each fitness variable: n, CRF= 17,928; n, MSF = 19,777; n, WC = 19,895; n, BMI = 19,904.
[b]SIMCE (Sistema de Medición de la Calidad de la Enseñanza; System for Measuring the Quality of Education) 2011 (229)
[c]Groups defined by Chilean Ministry of Education (308)
[d]Berdegue et al 2010 (216) ; n, urbanicity = 17,269
[e]Body mass index is classified according to the FITNESSGRAM 2011 health-related standards (262).
[f]Waist circumference is classified according to health-related cutpoints (299).
[g]Low musculoskeletal fitness is defined as a standing broad jump score <20th percentile of European adolescents (253).
[h]Cardiorespiratory fitness is classified according to FITNESGRAM 2011 aerobic capacity cutpoints (250).
[i]Aerobic capacity is estimated from 20mSRT using Leger equation (235).

Table 8.3.[†] Prevalence (95% CI) of **needs improvement - health risk body mass index**[e] by sociodemographic and other heath-related fitness characteristics in a population-based sample (N = 19,904)[a] of Chilean 8th grade students: The 2011 National Education Survey (SIMCE)[b]

	Males (n = 10,309)			Females (n = 9,595)		
Characteristic	Prevalence	(95% CI)	p, trend	Prevalence	(95% CI)	p, trend
Sociodemographic						
Age (yr)						
13-13.9	25.6%	(24.2%, 27.0%)	<0.001	30.9%	(29.5%, 32.4%)	<0.001
14-14.9	19.8%	(18.7%, 20.9%)		26.7%	(25.5%, 28.0%)	
15-15.9	19.1%	(16.8%, 21.5%)		25.4%	(22.0%, 28.8%)	
16-17.9	16.0%	(12.2%, 19.7%)		31.5%	(24.7%, 38.3%)	
Socioeconomic status[c]						
Low	21.0%	(18.7%, 23.2%)	0.01	31.5%	(28.8%, 34.3%)	<0.001
Low-middle	21.9%	(20.5%, 23.4%)		33.1%	(31.5%, 34.8%)	
Middle	23.3%	(21.9%, 24.7%)		28.2%	(26.7%, 29.8%)	
Middle-high	23.4%	(21.0%, 25.7%)		24.3%	(22.0%, 26.5%)	
High	13.2%	(11.0%, 15.3%)		14.2%	(11.6%, 16.8%)	
School Type						
Private	14.0%	(11.7%, 16.2%)	0.001	12.4%	(9.8%, 15.0%)	<0.001
Subsidized	22.7%	(21.5%, 23.9%)		28.0%	(26.7%, 29.3%)	
Public	22.1%	(20.9%, 23.3%)		31.4%	(30.0%, 32.7%)	
Urbanicity[d]						
Rural	21.2%	(19.8%, 22.6%)	0.50	30.5%	(28.9%, 32.2%)	0.001
Urban	20.6%	(19.5%, 21.6%)		27.3%	(26.1%, 28.5%)	
Region						
Santiago Metropolitan	19.8%	(18.6%, 21.1%)	<0.001	27.7%	(26.1%, 29.2%)	0.19
All other regions	29.0%	(27.8%, 30.1%)		22.7%	(21.7%, 23.8%)	
Health-related fitness						
Waist Circumference[f]						
Normal	3.2%	(2.8%, 3.6%)	<0.001	8.7%	(8.0%, 9.3%)	<0.001
High	63.2%	(61.5%, 64.9%)		73.5%	(71.9%, 75.1%)	
Musculoskeletal fitness[g]						
Normal	14.4%	(13.6%, 15.2%)	<0.001	22.0%	(21.0%, 23.1%)	<0.001
Low	39.3%	(37.5%, 41.0%)		40.9%	(39.2%, 42.5%)	
Cardiorespiratory fitness[h,i]						
Healthy	12.7%	(12.0%, 13.5%)	<0.001	15.0%	(13.8%, 16.1%)	<0.001
Needs Improvement	35.1%	(32.2%, 38.0%)		27.7%	(25.8%, 29.7%)	
NI - Health Risk	49.2%	(46.7%, 51.8%)		43.2%	(41.2%, 45.1%)	

[†]Abbreviations: CI, confidence interval; NI, needs improvement

[a]Working sample excludes individuals 18 years and older and with missing BMI. Sample sizes vary for each fitness variable: n, CRF= 17,928; n, MSF = 19,777; n, WC = 19,895; n, BMI = 19,904.

[b]SIMCE (Sistema de Medición de la Calidad de la Enseñanza; System for Measuring the Quality of Education) 2011 (229)

[c]Groups defined by Chilean Ministry of Education (308)

[d]Berdegue et al 2010 (216) ; n, urbanicity = 17,269

[e]Body mass index is classified according to the FITNESSGRAM 2011 health-related standards (262).

[f]Waist circumference is classified according to health-related cutpoints (299).

[g]Low musculoskeletal fitness is defined as a standing broad jump score <20th percentile of European adolescents (253).

[h]Cardiorespiratory fitness is classified according to FITNESGRAM 2011 aerobic capacity cutpoints (250).

[i]Aerobic capacity is estimated from 20mSRT using Leger equation (235).

Table 8.4. Prevalence (95% CI) of **high waist circumference**[f] by sociodemographic and other heath-related fitness characteristics in a population-based sample (N = 19,895)[a] of Chilean 8th grade students: The 2011 National Education Survey (SIMCE)[b]

	Males (n = 10,305)			Females (n = 9,590)		
Characteristic	Prevalence	(95% CI)	p, trend	Prevalence	(95% CI)	p, trend
Sociodemographic						
Age (yr)						
13-13.9	31.8%	(30.3%, 33.3%)	<0.001	30.6%	(29.1%, 32.0%)	0.67
14-14.9	31.0%	(29.7%, 32.2%)		30.9%	(29.6%, 32.3%)	
15-15.9	30.9%	(28.1%, 33.6%)		27.3%	(23.8%, 30.8%)	
16-17.9	18.4%	(14.4%, 22.3%)		38.6%	(31.5%, 45.7%)	
Socioeconomic status[c]						
Low	28.0%	(25.5%, 30.5%)	0.02	33.5%	(30.8%, 36.3%)	<0.001
Low-middle	31.4%	(29.8%, 33.0%)		35.3%	(33.6%, 37.0%)	
Middle	33.5%	(31.9%, 35.0%)		31.6%	(30.0%, 33.2%)	
Middle-high	31.4%	(28.9%, 33.9%)		24.2%	(21.9%, 26.4%)	
High	21.1%	(18.5%, 23.8%)		14.9%	(12.3%, 17.6%)	
School Type						
Private	21.5%	(18.8%, 24.2%)	0.01	13.6%	(10.9%, 16.3%)	<0.001
Subsidized	32.6%	(31.3%, 33.9%)		30.4%	(29.1%, 31.7%)	
Public	30.7%	(29.4%, 32.0%)		33.4%	(32.0%, 34.8%)	
Urbanicity[d]						
Rural	31.2%	(29.6%, 32.8%)	0.12	34.4%	(32.7%, 36.0%)	<0.001
Urban	29.7%	(28.5%, 30.9%)		28.3%	(27.1%, 29.5%)	
Region						
Santiago Metropolitan	27.9%	(26.4%, 29.3%)	<0.001	26.7%	(25.2%, 28.3%)	<0.001
All other regions	32.5%	(31.3%, 33.6%)		32.7%	(31.5%, 33.8%)	
Health-related fitness						
Body Mass Index[e]						
Healthy	6.4%	(5.8%, 7.0%)	<0.001	5.8%	(5.2%, 6.4%)	<0.001
Needs Improvement	43.3%	(41.0%, 45.6%)		31.2%	(28.9%, 33.6%)	
NI - Health Risk	89.7%	(88.4%, 90.9%)		79.0%	(77.5%, 80.5%)	
Musculoskeletal fitness[g]						
Normal	23.5%	(22.5%, 24.5%)	<0.001	25.2%	(24.1%, 26.3%)	<0.001
Low	48.3%	(46.5%, 50.0%)		41.0%	(39.3%, 42.6%)	
Cardiorespiratory fitness[h,i]						
Healthy	21.0%	(20.1%, 22.0%)	<0.001	18.5%	(17.2%, 19.8%)	<0.001
Needs Improvement	49.5%	(46.5%, 52.5%)		30.2%	(28.2%, 32.2%)	
NI - Health Risk	59.7%	(57.2%, 62.2%)		43.9%	(41.9%, 45.8%)	

[†]Abbreviations: CI, confidence interval; NI, needs improvement

[a]Working sample excludes individuals 18 years and older and with missing BMI. Sample sizes vary for each fitness variable: n, CRF= 17,928; n, MSF = 19,777; n, WC = 19,895; n, BMI = 19,904.

[b]SIMCE (Sistema de Medición de la Calidad de la Enseñanza; System for Measuring the Quality of Education) 2011 (229)

[c]Groups defined by Chilean Ministry of Education (308)

[d]Berdegue et al 2010 (216) ; n, urbanicity = 17,269

[e]Body mass index is classified according to the FITNESSGRAM 2011 health-related standards (262).

[f]Waist circumference is classified according to health-related cutpoints (299).

[g]Low musculoskeletal fitness is defined as a standing broad jump score <20th percentile of European adolescents (253).

[h]Cardiorespiratory fitness is classified according to FITNESGRAM 2011 aerobic capacity cutpoints (250).

[i]Aerobic capacity is estimated from 20mSRT using Leger equation (235).

Table 9.1.[†] Adjusted[‡] prevalence ratios (95%CI) for the effect of health-related fitness and sociodemographic characteristics on **needs improvement - health risk cardiorespiratory fitness**[g,h,i] in a population-based sample (N = 19,904)[a] of Chilean 8th grade students: The 2011 National Education Survey (SIMCE)[b]

	Males		Females		
Characteristic	Adjusted PR (95% CI)	p	Adjusted PR (95% CI)	p	Gender interaction p
Health-related fitness					
Body Mass Index[c]					
Healthy (ref)	ref		ref		
Needs Improvement	1.13 (0.95, 1.35)	0.17	1.31 (1.18, 1.46)	<0.001	0.16
NI - Health risk	1.88 (1.58, 2.24)	<0.001	1.62 (1.46, 1.80)	<0.001	0.15
High Waist Circumference (ref=normal)[e]	1.76 (1.50, 2.07)	<0.001	1.15 (1.05, 1.26)	0.003	<0.001
Low Musculoskeletal Fitness (ref=normal)[f]	2.72 (2.43, 3.04)	<0.001	1.83 (1.70, 1.97)	<0.001	<0.001
Sociodemographic					
Age 15-17.9 years (ref=13-14.9)	1.49 (1.35, 1.65)	<0.001	1.52 (1.43, 1.61)	<.0001	0.80
Low-middle-high Socioeconomic status (ref=high)[j]	1.28 (1.01, 1.62)	0.04	1.76 (1.43, 2.17)	<0.001	0.05
Urban (ref=rural)[k]	1.15 (1.03, 1.29)	0.01	1.20 (1.12, 1.29)	<0.001	0.57
Santiago Metropolitan (ref=all other regions)	0.96 (0.86, 1.07)	0.44	0.97 (0.93, 1.02)	0.26	0.79

[†]Abbreviations: PR, prevalence ratio; CI, confidence interval; NI, needs improvement; ref, reference group
‡Each prevalence ratio is adjusted for appearing sociodemographic and categorical fitness variables using a single log binomial model for the dichotomous fitness response variable.
[a]Working sample excludes individuals 18 years and older and with missing BMI. Sample sizes vary for each fitness variable: n, CRF= 17,928; n, MSF = 19,777; n, WC = 19,895; n, BMI = 19,904.
[b]SIMCE (Sistema de Medición de la Calidad de la Enseñanza; System for Measuring the Quality of Education) 2011 (229)
[c]Body mass index is classified according to the FITNESSGRAM 2011 health-related standards (262).
[e]Waist circumference is classified according to health-related cutpoints (299).
[f]Low musculoskeletal fitness is defined as a standing broad jump score <20th percentile of European adolescents (253).
[g]Cardiorespiratory fitness is classified according to FITNESGRAM 2011 aerobic capacity cutpoints (250).
[h]Aerobic capacity is estimated using Leger equation (235).
[i]Reference group when CRF is outcome is combined needs improvement plus healthy
[j]Five groups defined by Chilean Ministry of Education (308)
[k]Berdegue et al 2010 (216); n, urbanicity = 17,269

Table 9.2.[†] Adjusted[‡] prevalence ratios (95%CI) for the effect of health-related fitness and sociodemographic characteristics on **low musculoskeletal fitness**[f] in a population-based sample (N = 19,904)[a] of Chilean 8th grade students: The 2011 National Education Survey (SIMCE)[b]

	Males		Females		
Characteristic	Adjusted PR (95% CI)	p	Adjusted PR (95% CI)	p	Gender interaction p
Health-related fitness					
Body Mass Index[c]					
Healthy (ref)	ref		ref		
Needs Improvement	1.31 (1.19, 1.45)	< 0.001	1.10 (0.99, 1.21)	0.07	0.01
NI - Health risk	1.63 (1.46, 1.83)	< 0.001	1.26 (1.14, 1.39)	< 0.001	0.001
High Waist Circumference (ref=normal)[e]	1.04 (0.94, 1.15)	0.47	1.08 (0.99, 1.18)	0.10	0.60
Cardiorespiratory fitness[g,h]					
Healthy (ref)	ref		ref		
Needs Improvement	1.84 (1.68, 2.02)	< 0.001	1.67 (1.51, 1.84)	< 0.001	0.14
NI - Health risk	2.36 (2.18, 2.55)	< 0.001	2.41 (2.20, 2.63)	< 0.001	0.76
Sociodemographic					
Age 15-17.9 years (ref=13-14.9)	1.15 (1.07, 1.23)	< 0.001	1.10 (1.01, 1.21)	0.04	0.50
Low-middle-high Socioeconomic status (ref=high)[j]	2.09 (1.72, 2.54)	< 0.001	2.71 (2.13, 3.46)	< 0.001	0.10
Urban (ref=rural)[k]	1.02 (0.96, 1.09)	0.49	0.97 (0.91, 1.04)	0.40	0.28
Santiago Metropolitan (ref=all other regions)	1.03 (0.96, 1.09)	0.43	1.13 (1.05, 1.20)	0.001	0.06

[†]Abbreviations: PR, prevalence ratio; CI, confidence interval; NI, needs improvement; ref, reference group
‡Each prevalence ratio is adjusted for appearing sociodemographic and categorical fitness variables using a single log binomial model for the dichotomous fitness response variable.
[a]Working sample excludes individuals 18 years and older and with missing BMI. Sample sizes vary for each fitness variable: n, CRF= 17,928; n, MSF = 19,777; n, WC = 19,895; n, BMI = 19,904.
[b]SIMCE (Sistema de Medición de la Calidad de la Enseñanza; System for Measuring the Quality of Education) 2011 (229)
[c]Body mass index is classified according to the FITNESSGRAM 2011 health-related standards (262).
[e]Waist circumference is classified according to health-related cutpoints (299).
[f]Low musculoskeletal fitness is defined as a standing broad jump score <20th percentile of European adolescents (253).
[g]Cardiorespiratory fitness is classified according to FITNESGRAM 2011 aerobic capacity cutpoints (250).
[h]Aerobic capacity is estimated using Leger equation (235).
[i]Reference group when CRF is outcome is combined needs improvement plus healthy
[j]Five groups defined by Chilean Ministry of Education (308)

Table 9.3.[†] Adjusted[‡] prevalence ratios (95%CI) for the effect of health-related fitness and sociodemographic characteristics on **needs improvement - health risk body mass index**[c,d] in a population-based sample (N = 19,904)[a] of Chilean 8th grade students: The 2011 National Education Survey (SIMCE)[b]

	Males		Females		
Characteristic	Adjusted PR (95% CI)	p	Adjusted PR (95% CI)	p	Gender interaction p
Health-related fitness					
High Waist Circumference (ref=normal)[e]	16.63 (14.30, 19.35)	< 0.001	7.84 (7.09, 8.68)	< 0.001	< 0.001
Low Musculoskeletal Fitness (ref=normal)[f]	1.24 (1.16, 1.33)	< 0.001	1.08 (1.03, 1.14)	0.002	0.001
Cardiorespiratory fitness[g,h]					
Healthy (ref)	ref		ref		
Needs Improvement	1.32 (1.21, 1.44)	< 0.001	1.31 (1.20, 1.43)	< 0.001	0.896
NI - Health risk	1.47 (1.37, 1.59)	< 0.001	1.44 (1.33, 1.56)	< 0.001	0.694
Sociodemographic					
Age 15-17.9 years (ref=13-14.9)	0.88 (0.81, 0.97)	0.01	0.91 (0.83, 1.00)	0.052	0.628
Low-middle-high Socioeconomic status (ref=high)[j]	1.21 (1.04, 1.41)	0.01	1.25 (1.05, 1.48)	0.012	0.806
Urban (ref=rural)[k]	0.96 (0.90, 1.02)	0.16	0.97 (0.91, 1.02)	0.206	0.826
Santiago Metropolitan (ref=all other regions)	1.04 (0.98, 1.11)	0.21	1.05 (1.00, 1.11)	0.066	0.772

[†]Abbreviations: PR, prevalence ratio; CI, confidence interval; NI, needs improvement; ref, reference group
‡Each prevalence ratio is adjusted for appearing sociodemographic and categorical fitness variables using a single log binomial model for the dichotomous fitness response variable.
[a]Working sample excludes individuals 18 years and older and with missing BMI. Sample sizes vary for each fitness variable: n, CRF= 17,928; n, MSF = 19,777; n, WC = 19,895; n, BMI = 19,904.
[b]SIMCE (Sistema de Medición de la Calidad de la Enseñanza; System for Measuring the Quality of Education) 2011 (229)
[c]Body mass index is classified according to the FITNESSGRAM 2011 health-related standards (262).
[e]Waist circumference is classified according to health-related cutpoints (299).
[f]Low musculoskeletal fitness is defined as a standing broad jump score <20th percentile of European adolescents (253).
[g]Cardiorespiratory fitness is classified according to FITNESGRAM 2011 aerobic capacity cutpoints (250).
[h]Aerobic capacity is estimated using Leger equation (235).
[i]Reference group when CRF is outcome is combined needs improvement plus healthy
[j]Five groups defined by Chilean Ministry of Education (308)
[b]SIMCE (Sistema de Medición de la Calidad de la Enseñanza; System for Measuring the Quality of Education) 2011 (229)

Table 9.4.[†] Adjusted[‡] prevalence ratios (95%CI) for the effect of health-related fitness and sociodemographic characteristics on **high waist circumference**[e] in a population-based sample (N = 19,904)[a] of Chilean 8th grade students: The 2011 National Education Survey (SIMCE)[b]

	Males		Females		
Characteristic	Adjusted PR (95% CI)	p	Adjusted PR (95% CI)	p	Gender interaction p
Health-related fitness					
Body Mass Index[c]					
Healthy (ref)	ref		ref		
Needs Improvement	6.53 (5.81, 7.34)	<0.001	5.41 (4.63, 6.33)	<0.001	0.06
NI - Health risk	12.55 (11.29, 13.94)	<0.001	13.12 (11.49, 14.98)	<0.001	0.61
Low Musculoskeletal Fitness (ref=normal)[f]	1.00 (0.97, 1.03)	0.91	1.02 (0.97, 1.06)	0.43	0.55
CRF[g,h]					
Healthy (ref)	ref		ref		
Needs Improvement	1.16 (1.11, 1.21)	<0.001	1.08 (1.01, 1.16)	0.02	0.08
NI - Health risk	1.18 (1.14, 1.23)	<0.001	1.14 (1.07, 1.21)	<0.001	0.31
Sociodemographic					
Age 15-17.9 years (ref=13-14.9)	0.98 (0.94, 1.02)	0.34	0.97 (0.90, 1.05)	0.40	0.74
Low - middle-high Socioeconomic status (ref=high)[j]	0.99 (0.92, 1.07)	0.87	1.21 (1.02, 1.42)	0.03	0.03
Urban (ref=rural)[k]	1.00 (0.97, 1.03)	1.00	0.92 (0.88, 0.97)	0.001	0.003
Santiago Metropolitan (ref=all other regions)	0.96 (0.93, 1.00)	0.04	0.91 (0.85, 0.96)	0.001	0.07

[†]Abbreviations: PR, prevalence ratio; CI, confidence interval; NI, needs improvement; ref, reference group
‡Each prevalence ratio is adjusted for appearing sociodemographic and categorical fitness variables using a single log binomial model for the dichotomous fitness response variable.
[#]Regression impossible due to zeros in bivariate contingency table.
[a]Working sample excludes individuals 18 years and older and with missing BMI. Sample sizes vary for each fitness variable: n, CRF= 17,928; n, MSF = 19,777; n, WC = 19,895; n, BMI = 19,904.
[b]SIMCE (Sistema de Medición de la Calidad de la Enseñanza; System for Measuring the Quality of Education) 2011 (229)
[c]Body mass index is classified according to the FITNESSGRAM 2011 health-related standards (262).
[e]Waist circumference is classified according to health-related cutpoints (299).
[f]Low musculoskeletal fitness is defined as a standing broad jump score <20th percentile of European adolescents (253).
[g]Cardiorespiratory fitness is classified according to FITNESGRAM 2011 aerobic capacity cutpoints (250).
[h]Aerobic capacity is estimated using Leger equation (235).
[i]Reference group when CRF is outcome is combined needs improvement plus healthy
[j]Five groups defined by Chilean Ministry of Education (308)

APPENDIX

Table 10.[‡] Unadjusted relative risk[†] of having a missing cardiorespiratory fitness[e,f], musculoskeletal fitness[g] or urban vs. rural[d] value in working sample (N=19,904)[a] of Chilean 8th grade students[b] by other sociodemographic and health-related fitness characteristics.

	Cardiorespiratory fitness (n, miss = 1,976)		Musculo-skeletal fitness (n, miss=127)	Urban vs. rural (n, miss = 2,643)	
Characteristic	Boys	Girls	Both genders	Boys	Girls
Sociodemographic					
Gender (ref=male)	3.3***		NS	NS	
Age 15-17.9 (ref=13-14.9)	NS	NS	4.0 ***	0.8 *	NS
Socioeconomic status (5-group categorical)[c]	*	***	***	***	***
School type (ref=private)					
Subsidized	NS	2.1 ***	NS	NS	1.5 **
Public	NS	1.8 ***	3.7 *	NS	1.7 ***
Urban comuna (ref=rural)[d]	1.8 ***	1.4 ***	2.1 **	n/a	
Santiago region (ref=else)	1.6 ***	1.5 ***	1.8 ***	Greater Stgo is 100% urban	
Health-related fitness					
Low musculoskeletal fitness (ref=normal)[g]	2.4 ***	1.6 ***	n/a	1.2 ***	NS
High waist circumference (ref=normal)[i]	2.1 ***	1.4 ***	NS	1.2 **	NS
Needs improvement - Health Risk Body Mass Index[h] (ref=else)	2.8 ***	1.5 ***	NS	1.4 ***	NS
Needs improvement - Health Risk Cardiorespiratory fitness[e,f] (ref=else)	n/a	n/a	NS	1.6 ***	1.2 **

[†]Values shown are risk ratio of being missing compared to reference group, except categorical socioeconomic status where only chi-square p is shown. Values are only shown if chi-square test was significant at α=0.05.
[‡]Abbreviations: Ref, reference group; Miss, missing; Stgo, Santiago; NS, not significant at α=0.05
[a]Working sample excludes individuals 18 years and older and with missing BMI. Sample sizes vary slightly by demographic variable.
[b]SIMCE (Sistema de Medición de la Calidad de la Enseñanza; System for Measuring the Quality of Education) 2011 (cite)
[c]Groups defined by Chilean Ministry of Education (cite)
[d]Berdegue et al 2010; n, urbanicity = 17,269
[e]Cardiorespiratory fitnes is defined by VO2max. VO2max is estimated from 20mSRT using Leger equation (cite).
[f]Cardiorespiratory fitness is classified according to FITNESGRAM 2011 VO2max cutpoints (Welk 2011).
[g]Low musculoskeletal fitness is defined as a standing broad jump score <20th percentile of European adolescents (Ortega 2010).
[h]Body mass index is classified according to the FITNESSGRAM 2011 health-related standards (Laurson 2011).
[i]Waist circumference is classified according to health-related cutpoints (Messiah 2008).
***p<0.001
**p<0.01
*p<0.05

Table 11. Prevalence of healthy and unhealthy cardiorespiratory fitness defined by both the 2004 and the 2011 FITNESSGRAM cutoffs in a population-based sample (N=17,928)[a] of Chilean 8th grade students: The 2011 National Education Survey (SIMCE)[b]

Cardiorespiratory fitness[c] cut-offs	Males (n = 9,822)	Females (n = 8,106)	p[#]
2011 FITNESSGRAM[d]			
Healthy	74.2%	44.5%	<0.001
Needs Improvement	10.8%	24.8%	<0.001
Needs improvement - Health Risk	15.0%	30.7%	<0.001
2004 FITNESSGRAM[e]			
Healthy	76.5%	75.4%	0.08
Unhealthy	24.6%	23.5%	0.08

[a]Working sample excludes individuals > 18 years and with missing BMI. Sample sizes vary for each fitness variable: n, CRF= 17,928; n, MSF = 19,777; n, WC = 19,895; n, BMI = 19,904

[b]SIMCE (Sistema de Medición de la Calidad de la Enseñanza; System for Measuring the Quality of Education) 2011 (cite)

[c]Cardiorespiratory fitnes is defined by VO2max. VO2max is estimated from 20mSRT using Leger equation (cite).

[#]chi-square used to compare frequencies, logistic regression used to compare frequencies with >2 categories.

[d]Welk 2011.

[e]Meredith 2004.

IRB Letter of Exemption

EMORY UNIVERSITY | Institutional Review Board

April 9, 2013

Michael Garber
Rollins School of Public Health
1518 Clifton Road
Atlanta, GA 30322

RE: Determination: No IRB Review Required
IRB00061594 – *Health-related fitness in Chilean 8th graders: Applying ALPHA guidelines to 2011 Chilean national adolescent fitness data (SIMCE)*
PI: Michael Garber

Dear Mr. Garber:

Thank you for requesting a determination from our office about the above-referenced project. Based on our review of the materials you provided, we have determined that it does not require IRB review because it does not meet the definition of research involving "human subjects" as set forth in Emory policies and procedures and federal rules, if applicable. Specifically, in this project, you will be reviewing de-identified data collected by the Chilean Ministry of Health's System for Measuring the Quality of Education (SIMCE) between November 7, 2011 and November 30, 2011. You intend to use this data to determine the socio-demographic and body composition factors associated with low health-related fitness in 8th graders from all regions of Chile in 2011. With the data set you access, you will be unable to determine any individuals' identities. Accordingly, IRB review is not required.

45 CFR Section 46.102(f) defines "human subject" as follows:

> Human subject means a living individual about whom an investigator (whether professional or student) conducting research obtains (1) data through intervention or interaction with the individual, or (2) identifiable private information.

Please note that this determination does not mean that you cannot publish the results. If you have questions about this issue, please contact me. This determination could be affected by substantive changes in the study design, subject populations, or identifiability of data. If the project changes in any substantive way, please contact our office for clarification.

Thank you for consulting the IRB.

Sincerely,

Tom Penna, CIP
Research Protocol Analyst
This letter has been digitally signed

CC: Juan Leon

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