

Table 1: Cross-sectional and longitudinal studies examining the relation between physical activity, physical fitness and overweight in adolescents.

| Reference                  | Study design                                   | Anthropometrics                    | Cardio-respiratory fitness         | Motor fitness  | Objective physical activity | Subjective physical activity       | Results  |
|----------------------------|--|------------------------------------|------------------------------------|--|-----------------------------|------------------------------------|--|
| Deforche et al., 2003 [31] | cross-sectional; age: 12–18 years, N=3,214     | BMI [41], 5 skinfold thickness     | shuttle run                        | 10x5m shuttle run, standing broad jump, sit and reach, flamingo balance, plate tapping, sit ups, bent arm hang | -                           | sport index and leisure-time index | <u>Fitness:</u> speed shuttle run: sign. association with obesity (F= 134.4; p<0.001). endurance shuttle run: sign. association with obesity (F= 359.3; p<0.001). handgrip: sign. association with obesity (F= 40.9; p<0.001). plate tapping and sit and reach: similar for both groups.<br><u>PA:</u> no differences in leisure-time index. |
| Ng et al., 2006 [30]       | cross-sectional; age: 9–12 years, N=82         | BMI [41], WC, 5 skinfold thickness | shuttle run                        | -  | pedometers (2 days)         | -                                  | <u>Fitness:</u> sign. lower fitness scores in obese children (F= 21.0; p<0.001).<br><u>PA:</u> not sign. among body mass groups.   |
| Pate et al., 2006 [25]     | cross-sectional; age: 12 to 19 years; N= 3,287 | BMI [42]                           | submaximal treadmill exercise test | -  | -                           | MET sedentary activities           | <u>Fitness:</u> sign. higher CRF levels in normal weight than in overweight youth (p<0.001).<br><u>PA:</u> no analyses.  |

Sign. = significant; PA = physical activity; CRF = cardiorespiratory fitness; BMI = body mass index; MPA = moderate physical activity; MVPA = moderate-to-vigorous physical activity; VPA = vigorous physical activity; VVPA = very vigorous physical activity, WC = waist circumference; WHR = waist to hip ratio; LTPA = leisure-time physical activity; SSF = skinfold thickness; STF = truncal subcutaneous fat; PWC = physical work capacity

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| Ara et al., 2007 [29]   | cross-sectional; age: 7–12 years; N=1,068 | BMI [41], 6 skinfold thickness | shuttle run                | 10x5m shuttle run, flexibility, standing long jump, sit ups, handgrip, bent arm hang | -                           | categorized into active/not active   | <u>Fitness</u> : low correlations between fat mass and fitness parameters ( $r < 0.32$ ), (except for CRF: $r$ between 0.48 and 0.51; $p < 0.01$ and bent arm hang: $r$ between 0.36 and 0.40; $p < 0.01$ ). CRF: strongest correlation with BMI and fat mass compared to PA)<br><u>PA</u> : trend to lower values in skinfold thicknesses in the active group ( $p = 0.07$ ).   |
| Haerens et al. 2007 [8] | cross-sectional; age: 11–13 years; N=222  | BMI [41], BIA                  | Cooper test                | -  | accelerometer               | active transportation index, sports index, physical activity at school index, leisure-time physical activity index | <u>Fitness</u> : main effect of weight status ( $F = 36.63$ , $p < 0.001$ ) in the CRF. Sign. differences in the running capacity test ( $F = 46.17$ ; $p < 0.001$ ).<br><u>PA</u> : sign. differences in leisure time ( $F = 4.48$ ; $p < 0.05$ ); no sign. differences in total PA levels, school PA, active transportation and sport. Sign. association between overweight and MPA ( $F = 6.13$ ; $p \leq 0.05$ ). Sign. association between overweight and MVPA ( $F = 6.55$ ; $p \leq 0.05$ ). No sign. associations between overweight and total PA, active transportation, sport, school PA und LTPA. |

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| Ortega et al., 2007 [26]   | cross-sectional; age: 13–18.5 years; N=2,859 | BMI [41]; WC    | shuttle run                | -   | -                           | leisure-time PA index, active commuting to school, MET sedentary activities | <u>Fitness</u> : inverse correlation between BMI-adjusted WC and CRF ( $p \leq 0.05$ ).<br><u>PA</u> : no sign. associations between BMI ( $p > 0.05$ ) or WC ( $p > 0.05$ ) and LTPA.<br><u>Fitness &amp; PA</u> : inverse correlation between WC / BMI and CRF, independent of sedentary activities or PA (data not shown).<br>Association between lower obesity risk (when measured by WC) and fitness / sedentary activities, not in PA.  |
| Fogelholm et al., 2008 [6] | cross-sectional; age: 15–16 years; N=2,266   | BMI [41]        | shuttle run                | sit ups, sit and reach, back and forth jumping, five jump, ball skill test, coordination test | -                           | frequency of PA   | <u>Fitness</u> : significant effect of overweight for all tests, excluding sit and reach ( $p < 0.002$ ). Sign. association between five-jump, endurance shuttle run and fitness index and overweight ( $\beta$ -coefficients: -0.02 to -0.26; $p < 0.001$ ; $R^2$ : 0.14 to 0.32).<br><u>PA</u> : no differences between PA level and weight groups<br><u>Fitness +PA</u> : poorer results in all fitness tests for overweight regardless of PA levels. PA explained more variance in fitness test results than BMI. |

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|---------------------------|---|---|---|---------------|-----------------------------|---|---|
| Lohman et al., 2008 [32]  | cross-sectional; age: 14 years; N=1,440                       | high and weight, 1 skinfold thickness, percent fat (DXA, BMI, skinfold thicknesses) | PWC 170   | -             | actiGraph                   | -                                       | <u>Fitness:</u> correlation with PWC 170: fat free mass ( $r= 0.26$ $p<0.05$ ) fat mass ( $r= 0.16$ , $p<0.5$ ), body composition ( $r= -0.36$ to $-0.54$ ).<br><u>PA:</u> Inverse correlation between MVPA and BMI and MVPA and fat mass ( $r= -0.14$ and $r=-0.12$ , $p<0.05$ ).<br><u>Fitness + PA:</u> high level of PA, average %body fat: high fitness level.<br>Low level of PA, average %body fat: low fitness level.   |
| Aires et al., 2010 [7]    | cross-sectional; age: 11–18 years; N=111                      | BMI [41]  | shuttle run   | -             | accelerometer               | -                                       | <u>Fitness:</u> overweight youth: sign. lower CRF levels ( $p<0.05$ ); BMI inverse correlation with CRF ( $r=- 0.2$ , $p<0.05$ ); CRF pos. correlated with VPA ( $r=0.39$ , $p<0.001$ ), VVPA ( $r= 0.28$ , $p<0.001$ ), the amount of PA ( $r= 0.28$ , $p<0.001$ ). Higher levels of CRF: lower relative risk of being overweight/obese (OR=0.968 (0.939 to 0.998), $p=0.037$ ).<br><u>PA:</u> no associations between BMI level and total amount of PA or PA intensity. |
| Huotari et al., 2010 [27] | cross-sectional; age: 13–18 years; N=558 (2001); N=717 (1976) | BMI [41]  | 2,000-m running test (boys), 1,500-m running test (girls) | -             | -                           | frequency per week of PA outside school | No separate analyses for PA and CRF in relation to association with overweight, but regression model shows that LTPA ( $\beta$ : 0.23 to 0.30; $p<0.001$ ) and BMI ( $\beta$ : -0.10 to -0.42; $p<0.001$ ) significant predictors of CRF.   |

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| Ortega et al., 2010 [9] | cross-sectional; age: 15 years; N=518 | BMI [43], WC, skinfold thickness | maximal cycle test         | -             | activity monitor            | sedentary activities (TV time) | <p><u>Fitness:</u> negative association between WC and CRF (p=0.002).</p> <p><u>PA:</u> no associations between PA parameters and WC.</p> <p><u>Fitness+ PA:</u> no association between WC and VPA / total PA, but significant interactions with CRF (CRF and VPA: <math>\beta=0.01</math>, p=0.005; CRF and total PA: <math>\beta=0.01</math>; p=0.02); inverse association between WC and low CRF level and VPA (<math>\beta=-0.10</math>; p=0.04). No sign. associations between total PA and WC (<math>\beta=-0.08</math>; p=0.08); high fitness level: all PA parameters positively associated with WC (<math>\beta: 0.11</math> to <math>0.25</math>; p=0.025 to p&lt;0.001); prevalence of being overweight, having an excess of total fatness and having a high risk WC were sign. lower in the high CRF group than in the low CRF group (all p≤0.05). CRF: component of the model: moderate PA and MVPA sign. positively associated with WC (p=0.01 and p=0.03).</p> |

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|-----------------------------------|--|-----------------------|----------------------------|---|-----------------------------|--|---|
| Gonzales-Suarez et al., 2011 [28] | cross-sectional; age: 11–12 years; N=4,600 | BMI [41]              | shuttle run                | standing broad jump, 50-m sprint              | -                           | MVPA, physical activity score  | <u>Fitness:</u> sign. inverse association between overweight and standing long jump ( $p=0.001$ ) and overweight and CRF ( $p=0.001$ ). sign. inverse association between overweight and 50-m sprint ( $p=0.02$ ). Adolescents with lower median score in the standing broad jump and predicted CRF: higher odds ratio to be overweight (OR=3.1 (1.7 to 5.8) or obese (OR=9.1 (3.4 to 24.1)).<br><u>PA:</u> sign. inverse association between BMI and PA score ( $p=0.006$ ). Low PA: sign. higher odds ratio to be overweight or obese (overweight OR=4.6 (2.5 to 8.5), obese OR=10.8 (3.9 to 30.1). |
| Aires et al., 2010 [33]           | longitudinal; age: 11–16 years; N=345      | BMI (not categorized) | shuttle run                | back saver, sit and reach, curl ups, push ups | -                           | sport outside school in (non) organized sport (MVPA), sedentary activities (TV, PC time) | <u>Fitness:</u> sign. neg. association between BMI and fitness level ( $p<0.001$ ). High fitness level at baseline: lowest pos. changes in BMI over all measurements; low fitness at baseline: increased BMI.<br>Low fitness level at baseline: neg. changes in total PAI; pos. changes in BMI.<br><u>PA:</u> no analyses.  |

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| He et al., 2011 [5] | longitudinal; age: 8–13 years (T1); T2: 18 month later<br>N= 2,179 (T1);<br>N=1,795 (T2) | BMI [44]        | shuttle run                | -             | -                           | categorized into physical active / inactive | <u>Fitness</u> : CRF: sign. inverse correlation with BMI in both surveys ( $r=-0.73$ and $r=-0.74$ ; $p<0.001$ ); CRF inversely associated with the changes in BMI over the study period ( $\beta=-0.63$ ; $p<0.001$ ). Sign. higher CRF in normal weight or in physically active children ( $p<0.001$ ).<br><u>PA</u> : no sign. associations between PA and the changes in BMI. |

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