Physical Fitness in Young Adults Born Preterm

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abstract

BACKGROUND: Young adults born preterm have higher levels of cardiometabolic risk factors than their term-born peers. Muscular and cardiorespiratory fitness have important cardiometabolic and other health benefits. We assessed muscular, cardiorespiratory, and self-rated fitness in preterm-born young adults.

METHODS: We studied unimpaired participants of the ESTER (Ennenaikainen syntymä ja aikuisiän terveys [Preterm Birth and Early-Life Programming of Adult Health and Disease]) birth cohort study at age 23.3 (SD: 1.2) years: 139 born early preterm (EPT; <34 weeks), 247 late preterm (LPT; 34–36 weeks), and 352 at term (control group). We measured muscular fitness with the number of modified push-ups performed in 40 seconds and maximal handgrip strength of the dominant hand, cardiovascular fitness with heart rate at the end of a 4-minute step test, and self-rated fitness. Data were analyzed with linear regression.

RESULTS: Young adults born EPT (−0.8; 95% confidence interval: −1.5 to −0.1; adjusted for gender, age, and source cohort) and LPT (−0.8; −1.4 to −0.3) performed fewer modified push-ups than controls. Handgrip strength was 23.8 (0.9–46.8) N lower in EPT participants. Cardiorespiratory fitness, measured by submaximal step test, was similar. On a self-rated fitness scale (1–5), the EPT adults reported 0.2 (0.0–0.4) lower scores than controls. After adjustment for early-life confounders, the results remained. They attenuated after further adjustment for mediating factors.

CONCLUSIONS: Young adults born EPT and LPT had lower muscular fitness than controls, which may predispose them to cardiometabolic and other chronic diseases. Adults born EPT also perceived themselves as less fit than controls.

WHAT’S KNOWN ON THIS SUBJECT: Young adults born preterm have higher levels of cardiometabolic risk factors and lower physical activity than term-born peers. Earlier studies, limited to those born very preterm or at very low birth weight, also suggest lower physical fitness in this group.

WHAT THIS STUDY ADDS: Young adults born preterm have lower muscular fitness and rate themselves as being less fit than those born at term. There was no difference in cardiorespiratory fitness in this sample across the entire range of preterm birth versus the controls.


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Dr Tikanmäki designed and carried out the initial analyses, drafted the initial manuscript, and participated in data collection; Drs Tammelin, Sipola-Leppänen, Vääräsmäki, Eriksson, and Järvelin participated in the study design and data collection and reviewed and revised the manuscript; Ms Matinolli and Dr Miettola participated in the data collection and reviewed and revised the manuscript; Dr Kaseva participated in the study design (focus on the analyses) and reviewed and revised the manuscript; Dr Kajantie conceptualized and designed the study, was responsible for the data collection, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.
Adolescents and adults born preterm at very (<1500 g) or extremely (<1000 g) low birth weight report undertaking less physical activity than those born at term;6–8 although these associations have not been captured by studies with the use of an objective measurement of physical activity (eg, accelerometry).9,10 Lower muscular and cardiorespiratory fitness are also features of those born preterm with an extremely low birth weight.8,11 Few studies have assessed this in adolescents or adults born closer to term; a study in Swedish male conscripts was consistent with a graded relationship between lower length of gestation and lower maximal exercise capacity.12 This question is important because both cardiorespiratory and muscular fitness are independent predictors of cardiometabolic and musculoskeletal health13–15 and lower late-life mortality.16,17

We studied the association of early (<34 weeks) and late (34–36 weeks) preterm birth with muscular, cardiorespiratory, and self-rated physical fitness among young adults. We further examined the roles of prenatal and early-life factors as potential confounders and current health characteristics as mediators of fitness level.

METHODS

Participants

The participants were from the ESTER (Ennenaikainen syntymä ja aikuisiän terveys [Preterm Birth and Early-Life Programming of Adult Health and Disease]) Preterm Birth Study, which comprises 1890 young adults (Supplemental Fig 2). They were recruited among the 1986 Northern Finland Birth Cohort (49.8%) born in 1985–1986 and among all children (50.2%) born from 1987 to 1989 in the same geographical area, identified via the Finnish Medical Birth Register.5 In 2009–2011, 750 individuals with adequately verified lengths of gestation participated in a clinical study at 23.3 (SD: 1.2) years.18 Those who were pregnant (n = 18) or reported cerebral palsy (n = 6), mental disability (n = 7), and/or other severe physical disability (n = 3) were excluded, which left us with 139 participants born early preterm (EPT), 247 LPT, and 352 born after 37 completed weeks of gestation (referred to as “at term”) who served as controls. Of those invited as born EPT, LPT, and controls, 41.6%, 39.5%, and 35.9%, respectively, participated. According to a detailed nonparticipant analysis of the clinical examination, men were less likely to participate among the LPT and control groups; there was no difference in perinatal characteristics between participants and nonparticipants in any of the groups. When we compared participants of the clinical examination included in analyses of specific outcomes with those not included (Supplemental Fig 2), EPT participants were less likely to be included in analyses of handgrip strength (P = .04) and self-perceived fitness (P = .01).

Ethics

The study was approved by the Coordinating Ethics Committee at Helsinki and Uusimaa Hospital District. Participants provided written informed consent.

Perinatal Data

Perinatal data for participants recruited through the 1986 Northern Finland Birth Cohort came from the cohort database, originally collected from hospital and maternal welfare clinic records.13 We collected corresponding data for those invited through the Finnish Medical Birth Register. Length of gestation (determined by ultrasound in 62.7% and 53.1%, by last menstrual period in 36.8% and 46.9%, and from hospital records with no data on method of determination in 0.5% and 0.0% of preterm infants and controls, respectively)18 and diagnoses of maternal gestational diabetes, hypertension (gestational or chronic), or preeclampsia (including superimposed) according to prevailing criteria were confirmed by reviewing original hospital records.20,21 Small for gestational age (SGA) was defined as birth weight SD score < −2 SDs and large for gestational age as >2 SDs according to Finnish standards.22

Clinical Examination

Body weight and composition were assessed by using segmental multifrequency bioelectrical impedance (InBody 3.0; Biospace, Seoul, Korea). Spirometry was performed before physical fitness tests and repeated after inhalation of 400 μg salbutamol if spirometry suggested airflow obstruction.23–25 The participants completed questionnaires on their medical history, including history of asthma, medications, socioeconomic status, physical activity, and daily smoking. Childhood socioeconomic status was assessed as the educational attainment of the more highly educated parent. Physical activity level was calculated in metabolic equivalent (MET) hours per week on the basis of a questionnaire on (1)
light (assuming a value of 3 METs),
(2) moderate to vigorous (5 METs),
and (3) commuting from home to
work or study and back (4 METs)
physical activity.26,27

Outcomes

As a measure of short-term
endurance capacity of the upper
body and the ability to stabilize the
trunk, the participants performed
the 40-second modified push-up test.
The participant lay prone on a mat,
clasped hands behind his or her back,
performed a straight-leg push-up
with elbows completely straight in
the vertical position, touched 1 hand
on top of the supporting hand, and
returned to the prone position to
repeat the cycle. The participants
practiced 1 push-up cycle before
the test.28,29 For the handgrip test,
the maximal isometric strength of
the dominant hand was measured
by a dynamometer (Good Strength,
IGS01; Metitur Oy, Jyväskylä,
Finland) based on the strain-gauge
technique.29,30 Cardiorespiratory
fitness was measured by using the
Åstrand-Ryhming step test,31,32
during which the participant steps
on and off a bench (which was 33 cm
high for women and 40 cm for men)
repeatedly for 4 minutes at 23 steps
per minute, paced by a metronome.
Heart rate was monitored by a Polar
monitor (RS800CX training computer
and WearLink WIND transmitter;
Polar Electro Oy, Kempele, Finland)
and recorded immediately after the
test. Self-rated fitness was measured
with the following question: “How do
you consider your current physical
fitness?” The response alternatives
were very good, quite good, fair,
quite poor, and very poor.33 The scale
was reversed (1 = very poor, 5 = very
good) for clarity.

Statistical Methods

All analyses were performed by using
SPSS, versions 21.0 and 22.0 (IBM
SPSS Statistics, IBM Corporation,
Armonk, NY)). We compared
descriptive characteristics by
Student’s t test and χ² test and the
outcomes by using linear regression
with a significance level of <.05.
We tested for interactions between
2 variables (significance level of
P < .01) by including a product
term together with these variables.
Categorical adjusting variables were
entered as dummy variables, with a
separate dummy for missing values.
In model 1 we adjusted for gender,
age, and cohort. In model 2, we
further adjusted for the following parental
and early-life potential
confounders: educational attainment
of the more highly educated parent,
maternal gestational diabetes and
hypertension, and birth weight SD
score. In model 3 we additionally
adjusted for the following potential
adult mediators that may differ
between those born preterm and
at term: self-reported physical
activity,6,7 diagnosed asthma,34
height,6,7 body fat percentage,5
and smoking.35 For heart rate after
the step test, we also adjusted for
whether the participant had received
salbutamol in a bronchodilation test.
We identified specific covariates
altering the associations by adding
or removing the variables stepwise.
We reran the analyses after
replacing the adjustment for body fat
percentage with lean body mass. As
a sensitivity analysis, we also reran
the analyses (1) after exclusion of
subjects with asthma and (2) after
inclusion of subjects with a known
chronic condition affecting mobility
who were excluded from the main
analyses.

RESULTS

Participant characteristics are
shown in Table 1, and outcomes by
exposure group are shown in Table 2.
Correlations between the outcomes
and associations between covariates
and outcomes are shown in
Supplemental Tables 3 and 5 . There
was no interaction between the
association of gender and preterm
birth with the outcomes.

Modified Push-up Test

Mean handgrip strength was 352.1
(SD: 82.4) N among women and
643.1 (SD: 145.7) N among men.
Those born EPT had a 23.8-N lower
handgrip strength than did controls
when adjusted for gender, age,
and cohort. This difference was
attenuated after adjustment for
socioeconomic status and
pregnancy-related factors, mainly because
of adjustment for birth weight SD
score. Further adjustment for adult
characteristics, including body fat
percentage or lean body mass, had
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Table 3).

Step Test

Mean heart rate after the step test
was 160 (SD: 14) beats per minute
among women and 153 (SD: 16)
beats per minute among men. There
was no difference between either
of the preterm groups and controls.
When further adjusted for adult
characteristics, those born EPT had 2
beats per minute (P = .24) and those
born LPT 3 beats per minute (P = .02)
lower heart rate, indicating better
cardiorespiratory fitness. The change
in the mean difference was mainly
due to adjustment for adult body

     3
### TABLE 1 Perinatal, Neonatal, and Current Characteristics of the Young Adults Born Preterm and of the Control Group Born at Term

<table>
<thead>
<tr>
<th></th>
<th>EPT (n = 139)</th>
<th>LPT (n = 247)</th>
<th>Controls (n = 352)</th>
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<tr>
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<td>164.6</td>
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<tr>
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<td>.009</td>
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<td>Lean body mass, kg</td>
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<td>Men</td>
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<td>.92</td>
<td>63.4</td>
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<tr>
<td>Women</td>
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<td>.11</td>
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<td>Daily smoking</td>
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<td>.14</td>
<td>54</td>
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<td>.21</td>
<td>40</td>
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<td>41.7</td>
<td>.002</td>
<td>78</td>
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</table>
fat percentage (Fig 1, Supplemental Table 3).

**Self-rated Fitness**

Mean scores for self-rated fitness on a scale ranging from 1 (very poor) to 5 (very good) were 2.3 (SD: 0.8) for women and 2.6 (SD: 0.9) for men. Participants born EPT scored 0.2 points lower than controls. Better self-rated fitness correlated with better measurements of physical fitness. This correlation was weakest for handgrip strength, in particular among participants born EPT (Supplemental Table 4). The difference remained similar when adjusted for socioeconomic status and pregnancy-related factors and was attenuated when adjusted for adult characteristics (Fig 1, Supplemental Table 3), mainly due to adjustments for body fat percentage and physical activity level (data not shown).

**Sensitivity Analyses**

Participants with asthma had 23.0 N (95% confidence interval [CI]: 0.8 to 45.3) weaker handgrip strength, 3 beats per minute (95% CI: 0.2 to 6.2) higher heart rate after the step test, 0.2 points (95% CI: 0.0 to 0.4) poorer self-perceived fitness level, and a similar number of modified push-ups (0.2; 95% CI: −0.5 to 0.9) compared with those with no asthma (adjusted for gender, age, and cohort). We reran the analyses after the exclusion of participants with asthma. The results remained similar. We also reran the analyses to include physically impaired participants who were excluded from the original analyses. Again, the results remained. For the step test, we excluded those who had inhaled salbutamol during spirometry before the step test, and the results remained.

**Pre- and Neonatal Factors**

As a continuous variable, 1 week longer length of gestation predicted 0.1 (95% CI: 0.0 to 0.2) more push-ups and 0.02 (95% CI: 0.01–0.04) higher scores on the self-perceived fitness scale. One unit higher birth weight SD score predicted a 16.7 (95% CI: 9.9–23.5) N increase in handgrip strength. Participants born SGA...
TIKANMÄKI et al had a 70.0 (95% CI: 36.4 to 97.5) N weaker handgrip strength than did the remaining participants when adjusted for gender, age, cohort, and stage of preterm birth. No difference was seen for the other outcomes. When SGA participants were excluded, the differences in handgrip strength between groups were attenuated and became statistically nonsignificant. Other results remained similar.

Of the participants born EPT, 21 received supplementary oxygen for \( \geq 28 \) days after birth. Their fitness level was similar to that of the remaining participants born EPT.

DISCUSSION

Our main finding was that young adults born EPT and LPT performed fewer modified push-ups and those born EPT had lower handgrip strength in comparison with the control group. Cardiorespiratory fitness was, however, not lower. Young adults born EPT rated themselves as less fit than controls.

Muscular Fitness

In the modified push-up test, young adults born early or LPT performed, on average, 1 push-up less than controls. For comparison, 17-year-olds born at \( \leq 800 \) g performed 5–6 fewer push-ups and exhibited lower performance in other tests measuring muscular fitness than did controls.8 The difference in our study was not explained by socioeconomic status, pregnancy-related factors, or the level of current physical activity and lean body mass. An exception was adjustment for body fat percentage, which attenuated the associations. This suggests that the higher adiposity of adults born preterm may in part explain their lower performance in the modified push-up test because the test requires supporting one’s body weight.

Handgrip strength is a well-established predictor of future physical function, disease risk, and mortality.16,17,36–38 Low birth weight is consistently associated with reduced handgrip strength in children, adolescents, and adults. A meta-analysis reported age-adjusted results with \(~2\) kg (20 N) higher muscle strength per kilogram of higher birth weight.19 Our findings revealed a 2.4-kg (23.8-N) difference
in handgrip strength between the EPT group and controls. This difference was largely explained by the lower birth weight SD score of those born EPT. An approximate estimate of its consequences is provided by a meta-analysis reporting an overall summary hazard ratio of 0.93 for mortality associated with a 2.5-kg increase in handgrip strength.16

Cardiorespiratory Fitness

Contrary to our hypothesis, cardiorespiratory fitness measured by step test was not lower among young adults born preterm. The CI extended no further than 0.27 SDs from zero, indicating that we could exclude all but small differences between groups. Several, although not all,40 studies have shown lower cardiorespiratory fitness among children and young people born extremely (<28 weeks) or very (<32 weeks) preterm or at extremely or very low birth weight with the use of a maximal exercise test10,11,40–43 or a submaximal test8,41 as in our study. A study in 218 820 Swedish male conscripts showed that among those born at 32 to 36 weeks, maximal exercise capacity was 0.10 SD lower than among those born at term12; such a small difference would not have been detected in the current study. Together with these studies, our study suggests that lower levels of cardiorespiratory fitness are not present across the whole range of preterm births, at least at any meaningful level.44–46

Self-rated Fitness

Correlations between self-rated and objectively measured cardiorespiratory fitness were similar to those previously observed.47 They were also similar within groups, indicating that adults born preterm and at term estimate their fitness equally well. This finding was also true for the modified push-up test, whereas correlations between self-rated fitness and handgrip strength were weak. We are aware of 1 previous study reporting that young adults born with an extremely low birth weight expressed less physical self-confidence.48 The difference we found between EPT and control groups was relatively weak, 0.2-point lower scores. The association was not explained by socioeconomic status or pregnancy-related factors. However, adjustment for adult characteristics such as physical activity and body fat percentage attenuated the results, suggesting a mediating role in the association of EPT birth and self-perceived fitness. The role of leisure-time physical activity and BMI in determining self-perceived health and fitness has been shown earlier49 and is also supported by our results.

Implications

Lower muscular fitness is associated with early and possibly also LPT birth and may predispose persons born preterm to cardiometabolic diseases in concert with other risk factors, including higher blood pressure and impaired glucose regulation.2,3 Low muscular fitness is also associated with other health disadvantages, including poorer bone health,15 and is a well-established predictor of mortality in later adulthood.16,17 Lower muscular fitness may partly be a consequence of previously observed lower physical activity levels among young adults born preterm,5–8 which, in turn, could originate from poorer motor skills or reduced pulmonary function.50 Our findings2 emphasize the promotion of physical activity, in particular activity to enhance muscular fitness, across the whole range of preterm birth from early childhood onward.51 A healthy lifestyle adopted in childhood is likely to carry on into adulthood.52 In addition to these practical implications, our results concur with the large body of evidence from human and animal studies suggesting that individual differences in physical activity and fitness originate from early life.53

Strengths and Limitations

The strengths of our study include measurement of muscular fitness, assessed in 2 ways, and cardiorespiratory fitness and a study population enabling the evaluation of physical fitness across the full range of preterm birth. A detailed nonparticipation analysis5 raised little concern over participation bias. Participants of the clinical examination who could not be included in analyses of handgrip and self-perceived fitness were more likely to be born EPT; which would be expected to result in more conservative estimates. We had access to reliable and diverse perinatal data, including verified length of gestation. However, an accurate estimation of cardiorespiratory fitness would require maximal exercise testing with a direct measurement of oxygen uptake.

CONCLUSIONS

We found that young adults born preterm have lower muscular fitness, because individuals born either EPT or LPT performed fewer modified push-ups and those born EPT had lower handgrip strength. No difference existed in cardiorespiratory fitness. Young adults born EPT perceived themselves to be less fit than did controls. The differences we found may increase the risk of chronic adult disease in later life. Pediatricians and allied health professionals should call for the promotion of physical activity in children born both early and LPT, with a particular focus on promoting physical activity that enhances muscular fitness.

ABBREVIATIONS

CI: confidence interval
EPT: early preterm
LPT: late preterm
MET: metabolic equivalent
SGA: small for gestational age
REFERENCES


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Marjaana Tikanmäki, Tuija Tammelin, Marika Sipola-Leppänen, Nina Kaseva, Hanna-Maria Matinolli, Satu Miettola, Johan G. Eriksson, Marjo-Riitta Järvelin, Marja Vääräsmäki and Eero Kajantie

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