Aerobic Capacity, Strength, Flexibility, and Activity Level in Unimpaired Extremely Low Birth Weight (≤800 g) Survivors at 17 Years of Age Compared With Term-Born Control Subjects

Marilyn Rogers, BSR, PT/OT*; Taryn B. Fay, MS‡; Michael F. Whitfield, MD*§; Jill Tomlinson, CCHRA(C)*; and Ruth E. Grunau, PhD*‡§

ABSTRACT. Objectives. To compare aerobic capacity, strength, flexibility, and activity level in extremely low birth weight (ELBW) adolescents at 17 years of age with term-born control subjects.

Methods. Fifty-three ELBW teens of birth weight ≤800 g were assessed at 17.3 years (16.3–19.7 years; birth weight: 720 g [520–800 g]; gestation: 26 weeks [23–29 weeks]) along with term-born control subjects (n = 31) at age 17.8 years (16.5–19.0 years; birth weight: 3506 g [3068–4196 g]; gestation: weeks 40 [39–42 weeks]). ELBW and control teens were assessed by a pediatric physiotherapist and completed components of the Canadian Physical Activity, Fitness and Lifestyle Appraisal and a self-assessment fitness and activity questionnaire. Continuous data were analyzed using MANOVA (group, gender) followed by t tests; categorical data were analyzed using the χ² test.

Results. ELBW teens had lower aerobic capacity, grip strength, leg power, and vertical jump; could do fewer push-ups; had less abdominal strength as measured by curl-ups; had less lower back flexibility; and had tighter hamstrings. ELBW teens reported less previous and current sports participation, lower physical activity level, and poorer coordination compared with term-born control subjects. ELBW teens were also found to have more difficulty with maintenance of rhythm and cadence. Although ELBW teens rated themselves lower on all measures of sporting activity, they were as happy with their level of fitness as the control subjects.

Conclusions. Compared with term-born control subjects, there are significant differences in motor performance in unimpaired ELBW survivors in late adolescence, reflected in aerobic capacity, strength, endurance, flexibility, and activity level. We conclude that these differences in fitness and physical activity are related to the interaction of effects of premature birth on the motor system together with a more inactive lifestyle. These findings have potential implications for later adult health problems. Pediatrics 2005;116:58–65. URL: www.pediatrics.org/cgi/doi/10.1542/peds.2004-1603; premature infants, extremely low birth weight infants, follow-up studies, motor development, strength, flexibility.

ABBREVIATIONS. ELBW, extremely low birth weight; DCD, developmental coordination disorder; VLBW, very low birth weight; mCAFT, Modified Canadian Aerobic Fitness Test; CPAFLA, Canadian Physical Activity Fitness and Lifestyle Appraisal test.

Variations in muscle tone and problems with motor coordination are common in children of extremely low birth weight (ELBW; ≤800 g), but there are few data describing motor functioning and fitness in late adolescence in teens who are free of severe sensorimotor or cognitive impairments.

Long-term motor sequelae of prematurity have been documented extensively3-6,9 and predate the high-technology neonatal intensive care. A study by our group on the same cohort of ELBW children at 9 years of age found that 51% of the ELBW children who did not have neurosensory handicaps, ambulatory cerebral palsy, and/or low IQ were classified as having developmental coordination disorder (DCD) compared with 5% of the control children.6 Parents of ELBW teens have reported more clumsiness and below average performance in sports,10,11 and in self-report studies, ELBW teens have reported more clumsiness and less athletic competence.12,13

The majority of follow-up studies throughout childhood and the early teen years have shown that ELBW and very low birth weight (VLBW) children are significantly shorter and lighter and have lower BMI and smaller head circumference than normal birth weight children.11,14-17 Muscle strength may also be reduced, although differences become less apparent as teens get older. However, some studies of ELBW and VLBW survivors in late teens and early adulthood found no height or weight differences with catch-up growth to puberty in ELBW16 and VLBW children.21 Various studies have also shown that small for gestational age ELBW infants who did not experience catch-up growth throughout childhood remained smaller as adults, with 1 study finding that small for gestational age VLBW boys show the least catch-up growth.22

This study was undertaken to examine differences in physical activity, aerobic capacity, flexibility, and...
grip and trunk strength between ELBW (\(\leq 800\) g) teens and term-born control teens at the end of the adolescent growth spurt at 17 years of age. Participation in regular physical activity is a contributor to good overall health, whereas inactivity and poor physical fitness are now recognized as significant health risks. Lack of physical activity is a significant contributor to the increasing rate of childhood obesity in developed countries. Establishing early, adequate levels of fitness and activity may be particularly important in former tiny infants, who may be at risk for early-onset adult diseases such as diabetes, hypertension, ischemic heart disease, and strokes.

**METHODS**

**Participants**

**ELBW Study Group**

Between January 31, 1981, and February 9, 1986, 250 infants of birth weight \(\leq 800\) g were admitted to the provincial NICU in British Columbia. A total of 148 died in the neonatal period and 4 died after neonatal discharge, leaving 98 (39%) who survived to late adolescence. Nineteen of the children in this birth cohort were identified as having 1 or more major impairments at age 8.5 years and were excluded from the present study. For this purpose, major impairments were defined as IQ <70, nonambulatory cerebral palsy, visual impairment worse than 20/200 in the better eye with optimal refractive correction, or sensorineural hearing loss. Of the 79 eligible ELBW teens, 53 (67%) consented to a psychoeducational and motor study and participated at 17 years of age. The results of the psychoeducational portion are presented in a separate paper. The characteristics of the ELBW group are given in Table 1.

**Control Group**

A group of 31 teens who were born at born between October 1, 1983 and August 31, 1984 and have participated as longitudinal control subjects for our studies of the ELBW group since 3 years of age served as control subjects at 17 years. The characteristics of the control group are also given in Table 1.

**Measures**

ELBW and control teens received the same battery of tests and questionnaires. The assessment included height, weight, and head circumference measurements and components of the Canadian Physical Activity, Fitness and Lifestyle Appraisal (CPAFLA), an established standardized test produced by the Canadian Society for Exercise Physiology and Health Canada, which was administered by the physiotherapist (M.R.). Our assessment included the following components:

- **BMI**: the BMI score is a relationship between weight and height that is associated with body fat and health risk: BMI = body weight in kg/height in m\(^2\).
- **Modified Canadian Aerobic Fitness Test (mCAFT)**: aerobic fitness is a measurement of an individual's ability to deliver oxygen to working muscles. Oxygen consumption increases parallel to the increase in energy demand until the limit of the aerobic system has been reached. Subjects conducted a stepping sequence in time to preset recorded music, to generate a step-

**TABLE 1.** Subject Characteristics of ELBW and Control Teens

<table>
<thead>
<tr>
<th></th>
<th>ELBW Group (n = 53)</th>
<th>Control Group (n = 31)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at assessment, y, mean (range)</td>
<td>17.3 (16.3–19.7)</td>
<td>17.8 (16.5–19.0)</td>
</tr>
<tr>
<td>Birth weight, g, mean (range)</td>
<td>719 (520–800)</td>
<td>3306 (3068–4196)</td>
</tr>
<tr>
<td>Gestation, wk, mean (range)</td>
<td>25.8 (23–29)</td>
<td>40 (39–42)</td>
</tr>
<tr>
<td>Girls, %</td>
<td>68</td>
<td>45</td>
</tr>
<tr>
<td>Ventilation, d, mean (range)</td>
<td>55 (0–127)</td>
<td>0</td>
</tr>
<tr>
<td>Oxygen, d, mean (range)</td>
<td>106 (1–320)</td>
<td>0</td>
</tr>
<tr>
<td>Small for gestational age, %</td>
<td>17</td>
<td>0</td>
</tr>
</tbody>
</table>
Procedures
In accordance with the protocol approved by the Clinical Research Ethics Board of the University of British Columbia and the Research Review Committee of the Women’s and Children’s Health Centre of British Columbia, ELBW and control subjects were contacted by mail. Written informed consent was obtained from each teen and from a parent. ELBW and control teens were seen individually in the Neonatal Follow-Up Program at British Columbia’s Children’s Hospital by a qualified physiotherapist and data collected centrally as part of a larger study of this cohort.

Data Analysis
Multivariate analysis of variance (MANOVA) was used on the set of continuous measures (group [ELBW, control] × gender). Overall significance on MANOVA was followed by univariate tests. Statistical significance was set at $P < .05$. Categorical data from the questionnaires (eg, orthotic use, sports participation, back and/or leg pain) were analyzed by using $\chi^2$ analysis.

There were no significant differences in perinatal and sociodemographic characteristics between ELBW teens that were studied at 17 years of age ($N = 53$) and the remaining ELBW teens from the original regional birth cohort who could not be located or refused to participate in the study ($N = 26$). However, there were significantly more boys than girls who did not participate in the study ($P = .012$).

RESULTS

Height, Weight, and Head Circumference
The results of growth measurements of the 2 groups are given for boys and girls in Table 2. ELBW teens had significantly lower weight ($P = .009$), height ($P = .0001$), and head circumference ($P = .0001$). Statistically significant gender differences appeared in height ($P = .0001$) and head circumference ($P = .0001$), whereas there were no gender × group interactions.

Fitness Test (CPAFLA)

BMI and Aerobic Fitness
The results of the CPAFLA fitness test are presented in Table 3. There were no group or gender differences in BMI. ELBW teens had lower aerobic fitness capacity as measured by the mCAFT step test ($P = .035$), and boys had a better aerobic fitness score than the girls overall ($P = .0001$).

Muscle Strength
The ELBW group scored lower than control subjects on combined grip strength ($P = .0001$), right-hand grip strength ($P = .0001$), and left-hand grip strength ($P = .0001$). Overall, boys scored higher than girls for right, left, and combined grip strength ($P = .0001$). In addition, group × gender interactions were found for combined ($P = .009$), right ($P = .032$), and left grip strength ($P = .003$). The ELBW group scored lower than the control group on lower limb...
strength in vertical jump \( (P = .0001) \) and leg power \( (P = .0001) \). There were overall gender differences, with boys having more leg power \( (P = .0001) \) and higher vertical jump \( (P = .0001) \) than the girls.

Dynamic Muscle Endurance

ELBW teens could do fewer push-ups \( (P = .014) \) and partial curl-ups \( (P = .033) \) than the control teens, and boys performed better than girls at both the push-ups \( (P = .006) \) and the partial curl-ups \( (P = .027) \).

Flexibility

ELBW teens were less flexible than the control teens on measurements of trunk-forward flexion \( (P = .002) \) and right \( (P = .001) \) and left popliteal angle \( (P = .001) \). There were no gender differences in trunk-forward flexion, but girls had better flexibility than boys in right \( (P = .001) \) and left popliteal angle \( (P = .009; \text{Figs } 1 \text{ and } 2) \).

Reported Pain, Sports/Activity Participation, Coordination, and Rhythm

The results of the motor questionnaire are presented in Table 4. Overall, more boys participated in sports compared with girls \( (P = .014) \). ELBW teens participated less in sports than control subjects \( (P = .0001) \). In addition, ELBW teens reported less frequent participation in physical activity \( (P = .0001; \text{Fig } 3) \), with the boys being more active than the girls \( (P = .02) \). There were no differences between the ELBW and control groups in orthotic use, reported leg pain, or reported back pain. There were no differences between the groups in how much the teens reported that they enjoyed physical activity or their degree of satisfaction with their level of fitness. However, ELBW teens did report that they were less coordinated than their peers \( (P = .023) \), and the physiotherapist rated ELBW teens as having more difficulty establishing and maintaining rhythm and cadence during the step test compared with the control subjects \( (P = .0001) \).

DISCUSSION

This is the first study to examine multiple measures of motor and physical ability in late adolescence in ELBW survivors who were born at \( \leq 800 \text{ g} \) birth weight. Our ELBW teens were smaller than their peers and had specific areas of weakness in aerobic capacity, strength, endurance, flexibility, and general fitness as well as lower rates of general activity.

Growth Measurements and BMI

The differences that were found in weight, height, and head circumference between the ELBW and control groups are not surprising as many VLBW and ELBW studies have shown differences in growth throughout childhood and into adulthood. However, this is one of the first studies that followed both ELBW teens and an age-matched cohort longitudinally, demonstrating that these differences persist past childhood into late adolescence. Comparison of height, weight, and BMI with a peer group matched for age and socioeconomic status is very important as population standards for growth change over time and are influenced by racial and socioeconomic variables, with a tendency for each generation to grow taller in the developed world. We did not find differences in BMI, suggesting that although the ELBW teens were generally smaller than the control teens, they still scored within their expected weight for their height. However, this finding is in contrast to Saigal’s study of ELBW teens at 12 to 16 years of age and a recent study by Doyle et al showing that ELBW teens at 20 years of age attained a height that was consistent with their parents height but that their weight was comparatively heavy for their height as measured by the BMI.

We examined the weight outliers in our groups and did not find significant differences between the ELBW and control groups. We therefore did not find a tendency to higher BMI in ELBW young adults in this study. This could be attributable to the relatively small sample size, a difference being masked by a recent tendency toward obesity in the pediatric and adolescent population as a whole, or our group may not yet be old enough. There was also no significant difference in blood pressure between the 2 groups (using 1 clinical recording for each patient during the visit).

![Fig 1. Trunk-forward flexion in ELBW versus control teens.](www.pediatrics.org/cgi/doi/10.1542/peds.2004-1603)
Aerobic Capacity, Sports Participation, and Activity Level

Recent and continued participation in physical activity is an important determinant of current measurable fitness and flexibility. At the outset, therefore, it is difficult to know whether the lower scores on multiple measures in this study are attributable to fundamental differences as a result of extreme prematurity (eg, cardiorespiratory, muscular, or neurobiological compromise) or these findings partly or even predominantly reflect the lower physical activity lifestyle that the ELBW teens tend to choose.

Lower aerobic capacity found in the ELBW teens could be a result of teens' participating less in physical activity as a result of physical limitations, such as coordination difficulties and clumsiness, less social

Fig 2. Popliteal angle in ELBW versus control teens.

**TABLE 4.** Motor Questionnaire Results for ELBW and Control Teens

<table>
<thead>
<tr>
<th>Measures</th>
<th>ELBW Teens (n = 53, n (%)</th>
<th>Control Teens (n = 31, n (%))</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sports participation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous</td>
<td>33 (62)</td>
<td>29 (92)</td>
<td>*</td>
</tr>
<tr>
<td>Current</td>
<td>18 (34)</td>
<td>23 (74)</td>
<td>*</td>
</tr>
<tr>
<td>Back pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous</td>
<td>26 (49)</td>
<td>18 (58)</td>
<td>NS</td>
</tr>
<tr>
<td>Current</td>
<td>17 (32)</td>
<td>7 (22)</td>
<td>NS</td>
</tr>
<tr>
<td>Leg pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous</td>
<td>23 (43)</td>
<td>10 (32)</td>
<td>NS</td>
</tr>
<tr>
<td>Current</td>
<td>20 (38)</td>
<td>6 (19)</td>
<td>NS</td>
</tr>
<tr>
<td>Do you like physical activity? (Yes)</td>
<td>37 (70)</td>
<td>27 (87)</td>
<td>NS</td>
</tr>
<tr>
<td>Do you think you are as coordinated as most of your peers? (Yes)</td>
<td>42 (79)</td>
<td>30 (97)</td>
<td>†</td>
</tr>
<tr>
<td>Are you happy with your level of physical fitness? (Yes)</td>
<td>26 (49)</td>
<td>19 (61)</td>
<td>NS</td>
</tr>
<tr>
<td>Problem with rhythm and cadence? (Yes)</td>
<td>29 (55)</td>
<td>3 (10)</td>
<td>*</td>
</tr>
</tbody>
</table>

* P < .001.
† P < .05.

Fig 3. Participation in physical activity in ELBW versus control teens.

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**Fig 2.** Popliteal angle in ELBW versus control teens.

**Fig 3.** Participation in physical activity in ELBW versus control teens.
acceptance, or specific experience (eg, knowledge of the rules), or could be a consequence of parents' limiting the participation of ELBW teens in physical activity because of perceived disability or potential injury. In a psychosocial study on the same group, 24 ELBW teens viewed athleticism as having less personal and social importance compared with term-born control subjects, perhaps in an attempt to reconcile poorer athletic abilities. We found that very few ELBW teens have participated in organized sports in the past compared with control teens; for example, 62% of the ELBW teens participated in organized sports in the past compared with nearly all (94%) of the control teens at 17 years of age. Even fewer ELBW teens (34%) were currently participating in some type of sports activity at the time of the assessment compared with 74% of the control teens. In the British Columbia public school system, there is no curricular requirement to participate in physical education or organized sports beyond the end of grade 10 (age 16), so the lower rate of participation by the ELBW group reflects a lifestyle choice free of curricular obligation. In addition to participating less in organized sports, ELBW teens reported lower activity level overall, with 47% of ELBW teens participating in some type of physical activity at least once per week compared with 87% of the control teens. Surprising, more than half (53%) of the ELBW teens engaged in a type of physical activity less than twice per month. It is interesting that, despite these findings, there were no differences in how much the teens reported enjoying physical activity or their degree of satisfaction with their level of fitness. Perhaps this reflects a tendency of the less physically active to want to seem more accepting of physical activity when questioned specifically by a physiotherapist. Supporting our findings, a study of ELBW children at 11 years of age found that ELBW children had a lower level of fitness compared with normal birth weight children on a treadmill task, and the parents of ELBW children also identified their teens as being less active than the normal birth weight group. 25 It is interesting that the investigators in the treadmill study were unsure of whether the ELBW children's diminished effort on the task was limited by subtle pulmonary difficulty or poor exercise tolerance. Our findings of lower aerobic capacity may also be attributable to subtle subclinical functional pulmonary compromise; however, this question was not specifically addressed. Because of small sample size and gender differences, it was not possible in this study to evaluate the effect of being small for gestational age at birth or severity of neonatal lung disease on aerobic capacity at 17 years of age.

Strength and Endurance

No studies have examined strength in ELBW teens in late adolescence. In many occupations, physical strength and endurance are important attributes. As there were differences in growth measurements between the ELBW and control teens, we expected to find differences in strength between the 2 groups. Once again, the marked differences may be a result of the reduced participation in physical activity in the ELBW group, especially in push-ups, curl-ups, vertical jump, and leg power. This may also explain the differences in handgrip strength found between our groups, as handgrip strength is also strongly associated with levels of physical activity and health. 27, 28 As expected, boys in both groups had greater strength than the girls, yet the strength measurements of the ELBW boys were strikingly different from the same-age control boys.

Flexibility

The incidence of cerebral palsy is increased in the ELBW population; however, for this study, we excluded teens with nonambulatory cerebral palsy. Previous studies have demonstrated coordination and motor difficulties in ELBW children (eg, refs 3 and 6–8), but no studies to our knowledge have examined flexibility specifically in ELBW children and teens. Our findings of decreased flexibility in the ELBW teens compared with the control teens may be a result of less participation in physical activity but could also be attributed to an ongoing tendency to muscular tightness and minor tone abnormalities, seen frequently in ELBW preschoolers and potentially contributing to a diagnosis of DCD in some ELBW children at school age. The muscle tone and posture abnormalities in infancy described as transient dystonia of prematurity, by definition, are expected to decrease and eventually resolve with maturation; however, the persistent tightness in the hamstrings and lower back seen in ELBW teens suggests that some subtle features may persist and be related to prematurity per se. As expected, girls showed better overall flexibility than the boys, but the ELBW girls performed in a similar flexibility range as the control boys, indicative of decreased flexibility compared with the normal range of a female adolescent.

Coordination and Rhythm

Our findings that ELBW teens had more difficulty with establishing and maintaining cadence and rhythm may be an indication of ongoing coordination difficulties. Our current sample of ELBW children was composed of 15 (28%) teens who received a diagnosis of DCD at 9 years of age. However, after examining ELBW teens who received a diagnosis of DCD against ELBW teens who were in the original DCD sample at 9 years (N = 22) but did not receive a diagnosis of DCD, there were no significant differences in the way in which the DCD ELBW teens performed on the physiotherapy measures or the way in which they responded to the physiotherapy questions, with the exception of 1 question, which specifically addressed coordination. The teens who received a diagnosis of DCD at 9 years of age believed that they were not as coordinated as their peers compared with the teens who did not receive a diagnosis of DCD (P = .027). Motor clumsiness has been well documented in preterm infants (eg, refs 3 and 6–8), and it has been assumed that this was related to subtle perinatal brain injury. However,
some recent MRI studies of VLBW children in their early to middle teens have found that although they had smaller brain volumes, there was no relationship found between brain measurements and motor neurologic or coordination scores. Difficulties with movement integrated with rhythm are probably multifactorial in origin, reflecting subtle difficulties with integrative brain functions that are not yet identifiable on current methods of neural imaging.

Poor early coordination combined with low self-confidence may contribute to lack of establishment of healthy levels of physical activity in childhood as well as lack of common knowledge of and skills for group sports and activities (e.g., how to swim, catch a ball). This carries into young adulthood, contributing to poor self-image and lack of association with more socially and physically active peers. This may add to the overall tendency of ELBW teens to be more sedentary compared with their peers.

**Limitations**

One of the principal limitations of this study is the loss of 33% of the eligible patients. We believe that this reflects the change in consent procedure, as in previous follow-up studies of the same cohort our recruitment numbers were much higher. For this study, because of the age of the subjects, the participation and “appointment contract” was with the teen, rather than the parent as in previous studies on this cohort.

We excluded children with major neurosensory impairment evident at 9 years, as the objective of this study was to compare ELBW teens who were free of impairment with those with whom they would be competing in the adult world. However, these results are not generalizable to the complete ELBW survivor cohort in their late teens as the data obtained from this cohort excluded teens with serious neurosensory impairments. The ELBW cohort in this study comprised the smallest survivors of neonatal intensive care in the 1980s. Although these results may be broadly applicable to current tiny infant survivors of similar birth weight and gestational age in our NICUs, changes in intensive care techniques, survivors of lower birth weight and gestational age, access to neonatal care, and changing sociodemographic factors make direct application to the current tiny infant survivors difficult.

**CONCLUSIONS**

In late adolescence, ELBW teens remain smaller than their peers; participate less in physical activities; and have specific areas of weakness in terms of aerobic capacity, limb and core strength, and flexibility of the lower back and hamstrings compared with term-born control teens. These findings have potential implications for later health problems in the ELBW survivors. Recommendations for early intervention of former extremely low birth weight youths and teens should include early encouragement to be active and participate in noncompetitive physical activities with family and peers. This should contribute to the establishment of a foundation for a healthy, active lifestyle that will support establishing peer relationships, social skills, and self-confidence in this vulnerable population.

**ACKNOWLEDGMENTS**

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**REFERENCES**


24. Grunau RE, Whitfield MF, Fay T. Psychosocial and academic characteristics of extremely low birth weight (<800 g) adolescents who are free of major impairment compared with term-born control subjects. *Pediatrics*. 2004;114(6). Available at: www.pediatrics.org/cgi/content/full/114/6/e725


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