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Impact of prematurity on exercise capacity and agility of children and youth aged 8 to 18☆

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ABSTRACT

Background: Preterm (PT) birth and low birth mass (LBW) can impair growth and development of children and may therefore affect their physical performance up to adulthood.
Aims: Our aim was to evaluate long-term consequences of prematurity, especially (an)aerobic exercise capacity and agility up to adulthood, by comparing premature and full-term (FT) individuals.
Study design, subjects: From 474 subjects born in 1987, who were enrolled into a longitudinal study, 396 (178 PT and 218 FT (with 127 of them LBW)) were followed-up into their early adulthood. Their mass, respiratory status at birth, and results of SLOfit monitoring system (i.e. results of exercise capacity and agility) were monitored on a yearly basis from their age of 8 to 18 years. Data were compared statistically with Student t-test or ANOVA.
Outcome measures, results: PT (or LBW) individuals performed aerobic (time of 600-meter run of females) and the majority of anaerobic tests (sit-ups, standing broad jump, and time of 60-meter run, but not bent arm hang) worse ($p < 0.05$) than FT individuals. Before puberty, however, the agility and fine motor tests (arm plate tapping, polygon backwards, and standing reach touch) were performed better ($p < 0.05$) by PT (or LBW) females, as compared to their FT peers, with no similar results in males.
Conclusions: Our results clearly demonstrate that prematurity (especially extreme prematurity) diminishes exercise capacity and agility on the long-term scale, therefore, PT children should be encouraged towards more regular participation in physical activities from early childhood onwards.

1. Introduction

Growth and development are interesting, complex, and multifactorial physiological processes. Previous research [1–3] in this field has contributed to the understanding of growth and developmental processes of full-term (gestational age 37 to 42 weeks; FT) and preterm (< 37th week; PT) individuals [2]. Within PT infants, one can distinguish between moderately (32–37 weeks; MPT) and very preterm (< 31 6/7 weeks; VPT) [2] individuals. Other definitions classify different groups of infants according to their birth mass on infants with low birth mass (birth mass < 2500 g; LBW[1]), which include individuals with extremely low (< 1000 g; ELBW), very low (< 1500 g; VLBW), and moderately low (1500 to 2500 g; MLBW), and those, who are heavier than 2500 g (normal birth mass; NBW) [3]. Preterm birth and low birth mass increase the risk of prenatal morbidity [4], mortality in childhood [5], the risk of diseases in adulthood [1], and can impair growth and development [6].

Some studies observed psychomotor development of premature children [7,8]; however, we were unable to identify research evidence on somatic developmental processes from birth all the way up to early adulthood. The development of PT infants is often less predictable than that of FT infants due to developmental lags and incomplete catch-up

Abbreviations: ELBW, extremely low birth mass; FT, full-term; LBW, low birth mass; MLBW, moderately low birth mass; MPT, moderately preterm; NBW, normal (appropriate) birth mass; PT, preterm; SGA, small for gestational age; VLBW, very low birth mass; VPT, very preterm

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[1] A term "low body weight" and the abbreviation of "LBW" is usually used in scientific literature (similarly for other categories). This term, however, is scientifically incorrect, as "weight" is by definition a force exerted on the object due to gravity, with Newtons (N) (and not kg) for its unit. Therefore, throughout the text, the term "weight" is replaced with the correct term "mass".

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periods that occur during their growth [9] and result in lower and lighter individuals [2,10] with potentially affected metabolic status in childhood and puberty [11,12]. Apart from the postnatal catch-up growth interval, the adolescent growth spurt is a period of accelerated growth, which provides another opportunity for PT children to close the developmental lag with their peers [10]. Additionally, long term development of prematures can also be related with different medical problems, of which respiratory morbidity has been suggested as an important factor that can cause decreased lung function later on in school period [13,14] and may thus reduce exercise capacity.

Children's physical development is reflected in their exercise capacity and agility, thus in the development of muscle strength, endurance, and coordination [15]. It was reported that together with cognitive and behavioural problems, minor motor problems are the most dominant neuro-developmental sequelae in PT [16] and VLBW [17] children, with the prevalence reported of up to 50–70% [18]. It was suggested that with every week of reduced gestation, corticomotor excitability may be reduced, which can remain evident in preschool years [19] and late childhood [20–22] in the form of poorer motor skill development. In contrary, to our knowledge, data on exercise capacity and motor performance of PT individuals during and after the adolescent growth spurt are by now very scarce [23] or even nonavailable, therefore we investigated, whether the consequences of prematurity, such as lower exercise capacity and agility, will be detected in this period.

2. Methods

A case-control study included all PT infants (N = 222) born in the period between March 9 and September 9 of 1987 in the Maternity Hospital Ljubljana, Slovenia, and every first FT infant (control group, N = 252) born immediately after a PT infant (254 males, 220 females) [24]. For all subjects, gestational age at birth [weeks], calculated from the date of last menstrual period, body mass [kg], and respiratory status (including duration of treatment with fraction of inspired oxygen above 0.4 ($FIO_2 > 0.4$), ventilatory support, or presence of respiratory distress) at birth were recorded.

We followed PT and FT individuals from their birth up to their late adolescence (or even into early adulthood) by using, combining, and analysing three different pre-existing data sources: Slovenian perinatal database that includes birth data of all Slovenian newborns; the aforementioned research study, which followed subjects yearly from birth up to the age of 3, and then again at 11 years of their age [24]; and the SLOfit monitoring system. The study protocol was approved by the Ethics Committee of the Republic of Slovenia (No. 64/07/2011) and was in accordance with the Declaration of Helsinki.

We encouraged individuals, who participated in the 1987 study, to voluntarily enrol to the present study and to provide a written informed consent for letting us combine their data from the above mentioned databases.

For 396 initially enrolled individuals (Table 1), regular standardised assessments of their motor development were performed during their schooling years. The SLOfit monitoring system is a national system for systematic monitoring of physical growth, exercise capacity, and agility of children and youth, which includes all Slovenian primary- and secondary-school pupils from the age of 6 (or 7) to 18 (or 19) years, whose parents provide informed consent for their children's enrolment and subsequent research data processing. The system uses the same standardised tests and the same protocol in all schools across the country and has been performed annually in April from the school year 1982/1983 onwards [25]. The following data of our subjects were acquired for each year of schooling: aerobic test result (i.e. the time of 600-meter run [s]), anaerobic test results (number of sit-ups [No. of repetitions]; distance of long jump (from the standing position with both feet together), hereinafter standing broad jump [cm]; the time of hanging on the pole with bent arms, hereinafter bent arm hang [s]; and the time of 60-meter run [s]), as well as agility and fine motor test results (the speed of touching panels with a hand, hereinafter arm plate tapping [No. of repetitions in 20 s]; time of walking backwards quadrupedally over the standard polygon [s]; and the extent of bowing forward, hereinafter stand and reach [cm]) [26].

For the purpose of the study, the subjects were classified into groups according to their gestational age at birth, thus into a PT (additionally into VPT and MPT) and FT group, and according to their birth mass into a LBW (additionally into VLBW and MLBW) and NBW group.

Average and standard deviation (SD) of each variable were calculated for the study groups. Differences between the absolute results of FT group and the two PT groups were calculated for each SLOfit test and for each age separately by subtracting the FT from the VPT (or MPT) results.

Data between VPT, MPT, and FT, as well as between VLBW, LBW, and NBW individuals were compared for each subjects' age with a one-way-ANOVA. Additionally, VPT and FT, as well as VLBW and NBW individuals were compared for each subject's age with Student's *t*-test. The level of 0.05 was adopted as statistically significant.

3. Results

Distribution of subjects according to their gestational age and birth mass, as well as their physical and respiratory status at birth is presented in Table 1.

Average absolute values (SD) of aerobic, anaerobic, and agility and fine motor tests for the FT study group are presented in Table 2, relative differences between VPT and MPT groups with respect to the FT group are presented on, on which FT results correspond to the value 0 (i.e. the abscissa) for each age.

3.1. Exercise capacity and agility of VPT, MPT, and FT individuals

The results of general aerobic endurance (600-meter run) were statistically similar between VPT, MPT, and FT males, except at 14 years, when PT males ran faster ($p < 0.05$) than their FT peers. VPT females were significantly slower ($p < 0.05$) than their peers at 8 and 15 to 18 ($p = 0.06$) years.

In puberty, anaerobic tests were mostly performed worse by PT than by FT individuals. Sprint speed (60-meter run) was significantly lower ($p < 0.05$) in PT than in FT males from the age of 10 to 12 years, and with the same trend at 8 and 13 years ($p = 0.06$ and 0.07, respectively). PT (especially VPT) females ran significantly slower ($p < 0.05$) at 8, 9, 17, and 18 years. Explosive power (standing broad jump) was significantly lower ($p < 0.05$) in PT males than in their FT peers from the age of 8 to 13 years and at 15 and 17 years of age (with the lowest values in VPT observed at 11 years). In females, the same difference between PT and FT individuals was present at 9, 11, 12, and 15 years. Significantly smaller ($p < 0.05$) trunk strength (number of sit-ups in 60 s) was evident in PT males when compared to their FT peers (with the lowest values observed in VPT individuals) at 8 to 12 and 18 years ($p = 0.05$). In females, the same trend was evident at 17 years ($p = 0.09$). Muscular endurance of shoulder girdle and arms (bent arm hang) was worse ($p < 0.05$) in PT males than in FT peers, with the lowest values in MPT individuals at the ages of 10 and 11 years, but with the longest duration (i.e. the best results) in VPT males at 8, 10, and 12 ($p = 0.07$) years of age. PT females tended to hang less time on the pole at 9 ($p = 0.07$) and 11 years ($p = 0.09$) than their FT peers, with VPT females having the worst ($p < 0.05$) results at 17 years of age.

Agility and fine motor tests were mostly performed better by PT individuals up to puberty (which was particularly evident for females), later on FT peers performed better. Coordination of body movements (polygon backwards) was worse ($p < 0.05$) in MPT males than in their VPT and FT peers at 10, 11, 14, and 17 years, with the same trend at 9 and 18 years ($p = 0.09$). In contrary, PT females, especially MPT