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MINI-SYMPOSIUM: LUNG FUNCTION IN PRESCHOOL CHILDREN

Spirometry in the pre-school age group

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Summary Spirometry is a widely used lung-function test in school-aged children and adults. It can also be used to test lung function in the pre-school population, provided that they are tested in a child-friendly setting, by experienced paediatric-orientated personnel and in a way that is congruent with their development. Accurate results can be obtained provided care and attention are paid to applying quality-control criteria suitable for this age group. The biggest challenge is to make the testing fun.

INTRODUCTION

Spirometry is used to record a forced expiratory vital capacity (FVC), the maximal volume that can be forcibly expired after inspiration to total lung capacity (TLC), as a volume–time plot. From this volume–time plot, timed forced expiratory volumes can also be calculated (FEV_t). The most widely used is the forced expiratory volume in 1 s (FEV_1), but volumes expired in 0.5 or 0.75 s ($FEV_{0.5}$ and $FEV_{0.75}$) can also be measured. Normal values for these have been developed in young children as by 1 s of forced expiration many have achieved full FVC. Flow–volume curves can also be plotted from the same forced expiratory manoeuvre and the flow at a particular percent of FVC can be calculated. MEF_{75} is the flow when 75% of FVC remains in the lungs, MEF_{50} is the flow at 50% of FVC and MEF_{25} is the flow when 25% of FVC remains in the lungs. MMEF is the maximal mid-expiratory flow (i.e., between 25 and 75%).

Spirometry is the mainstay of lung-function testing within the clinic setting and allows measurement of FEVs and flows in individuals from school age to old age. Until now pre-school age children (here using the *Index Medicus* definition as the period between a child's second and sixth birthdays) have been excluded from undertaking spirometry due to their perceived in-coordination and poor cooperation. With the advent of children being tested by paediatricians, paediatric nurses and paediatric-orientated technicians and the development of newer techniques and software for obtaining data, this has now changed and many paediatric lung function laboratories are undertaking pre-school spirometry. This review will focus on the practical aspects of undertaking spirometry in 2–6 year olds. Quality-control issues that enable accurate reporting of results will also be covered.

LABORATORY ENVIRONMENT AND STAFF

No child will cooperate with any test if they feel intimidated so as with any other paediatric setting the laboratory needs to be child friendly. A child-sized table and chairs, with crayons and pictures to colour in is an important step to reassuring the child that what follows will be fun. The most important asset is a respiratory technician/tester who is child friendly and can quickly gain the child's trust. They must also be able to teach and encourage the child in an age-appropriate manner. Time spent explaining the procedure and talking to the parents is also important, as the

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parents trusting the technician will further reassure the child. This initial time before any attempts at spirometry has been highlighted as once the child feels unsettled it is difficult to persuade them to perform to the best of their abilities and you will not be able to obtain true results.

TEACHING THE FORCED EXPIRATORY MANOEUVRE

Spirometry requires a forced expiratory manoeuvre which requires:

- a full inspiration to total lung capacity,
- a forceful, i.e. hard and fast, expiration,
- and continues to residual volume (RV), which is the hardest step as expiring beyond functional residual capacity (FRC) is uncomfortable.

All this needs to be as a single, smooth manoeuvre. The average 3.5-year-old, however, has a developmental level that will process and carry out three-step commands only.[1] This means that the forced expiratory manoeuvre needs to be broken down and taught in a manner that is appropriate to the child's development, with plenty of encouragement and positive re-enforcement. This stage of development also explains why the vast majority of 2-year-olds are unable to perform spirometry.

BREATH-ACTIVATED COMPUTER ANIMATION PROGRAMS (INCENTIVES)

Several of the spirometry manufacturers have developed breath-activated computer animation programs to use during testing. It is, however, very important that the animation program used is appropriate for both the child's age and the step being taught. For example, Jaeger has an animation program using candles (Fig. 1). This is appropriate for most ages, but only encourages peak expiratory flow; there is no incentive to encourage prolongation of the expiration down to residual volume. For this the balloon or bowling ball (Fig. 1) animation programs are more appropriate. The facility to alter the difficulty of the animation programs should be available. This alteration may be necessary so that the child feels the target is achieved without losing hope and giving up.

The ideal situation for an animation program like the bowling ball is that the bowling ball is blown four-fifths of the way to the skittles by the peak flow and then the remaining distance is covered when the child exhales down to residual volume. The difficulty should be set so that the child doesn't quite knock the skittles down but feels they were so close that they can do so next time. This will encourage the child to try harder and they may then replicate the manoeuvre. This means that the child has produced a maximal flow that is reproducible. If the skittles are knocked over then there is the possibility that the child will stop once the target is achieved and so not reach residual volume.

REWARD AND POSITIVE RE-INFORCEMENT

Each manoeuvre takes a few seconds, many less than 1 s; so most children will happily perform 15 blows within a 5-min period. Once the tester is satisfied that several maximal effort blows have been achieved then the child can be rewarded. This can be done by reducing the difficulty so the

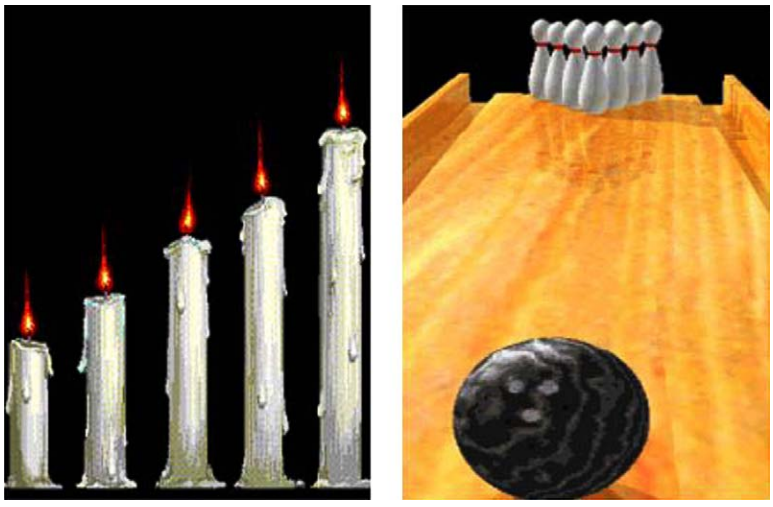

Figure 1 Two examples of breath-activated computer animation programs. The candles encourage a forceful expiration, i.e., peak flow and the bigger the peak flow the more candles will be blown out, further prolongation of the expiration will not blow out any more candles. In contrast, a forceful expiration will blow the bowling ball a long way towards the skittles and prolongation of the expiration will blow the bowling ball further towards the skittles with the aim of knocking them over.